AIM Multi-gas Model Analysis on stabilization scenarios

Junichi Fujino, Toshihiko Masui, Rajesh Nair, Mikiko Kainuma, Yuzuru Matsuoka

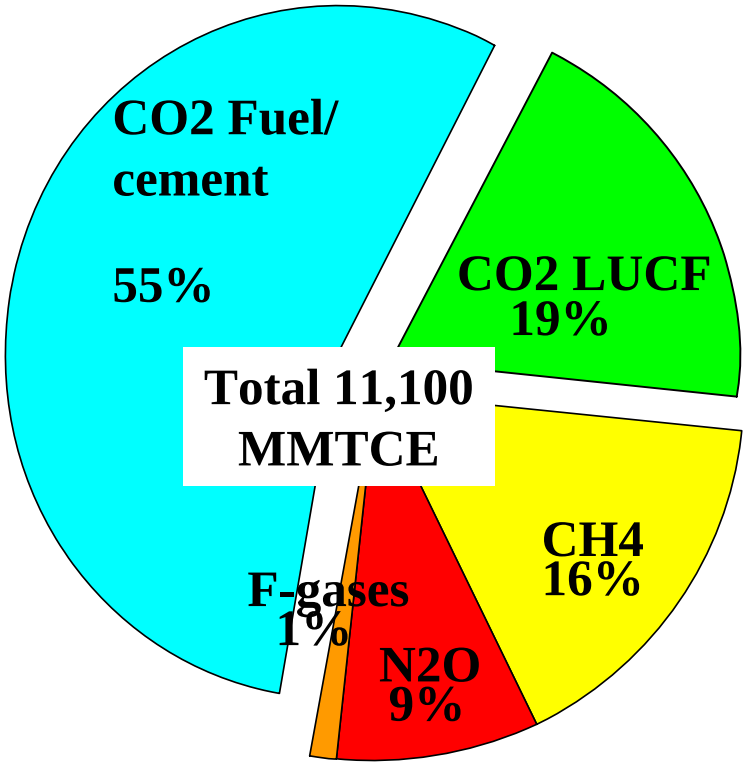
AIM (Asia-Pacific Integrated Model) team

NIES (National Institute for Environmental Studies), Japan

Kyoto University, Japan

Workshop on GHG Stabilization Scenarios

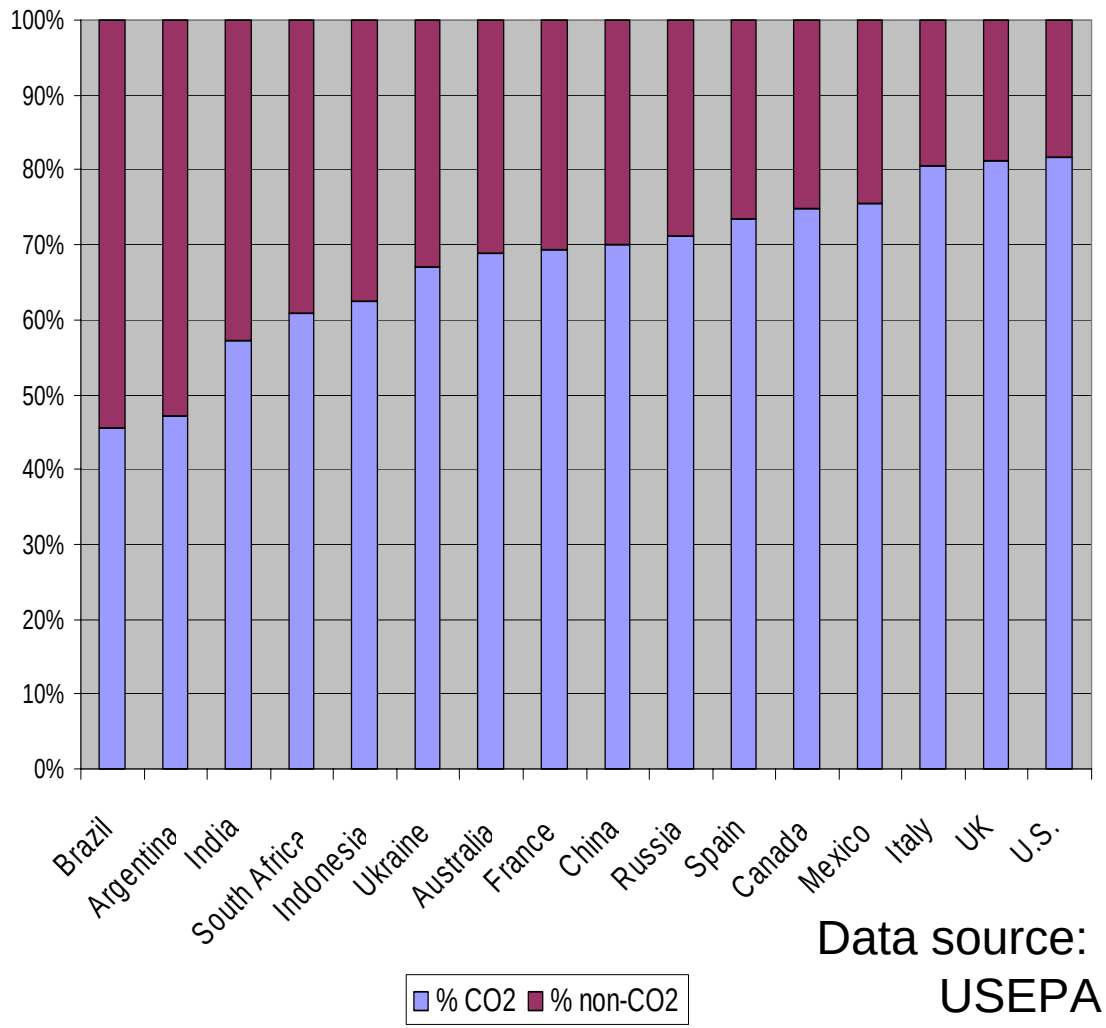
Tsukuba, Japan on January 22-23, 2004



2000 Global Net GHG Emissions

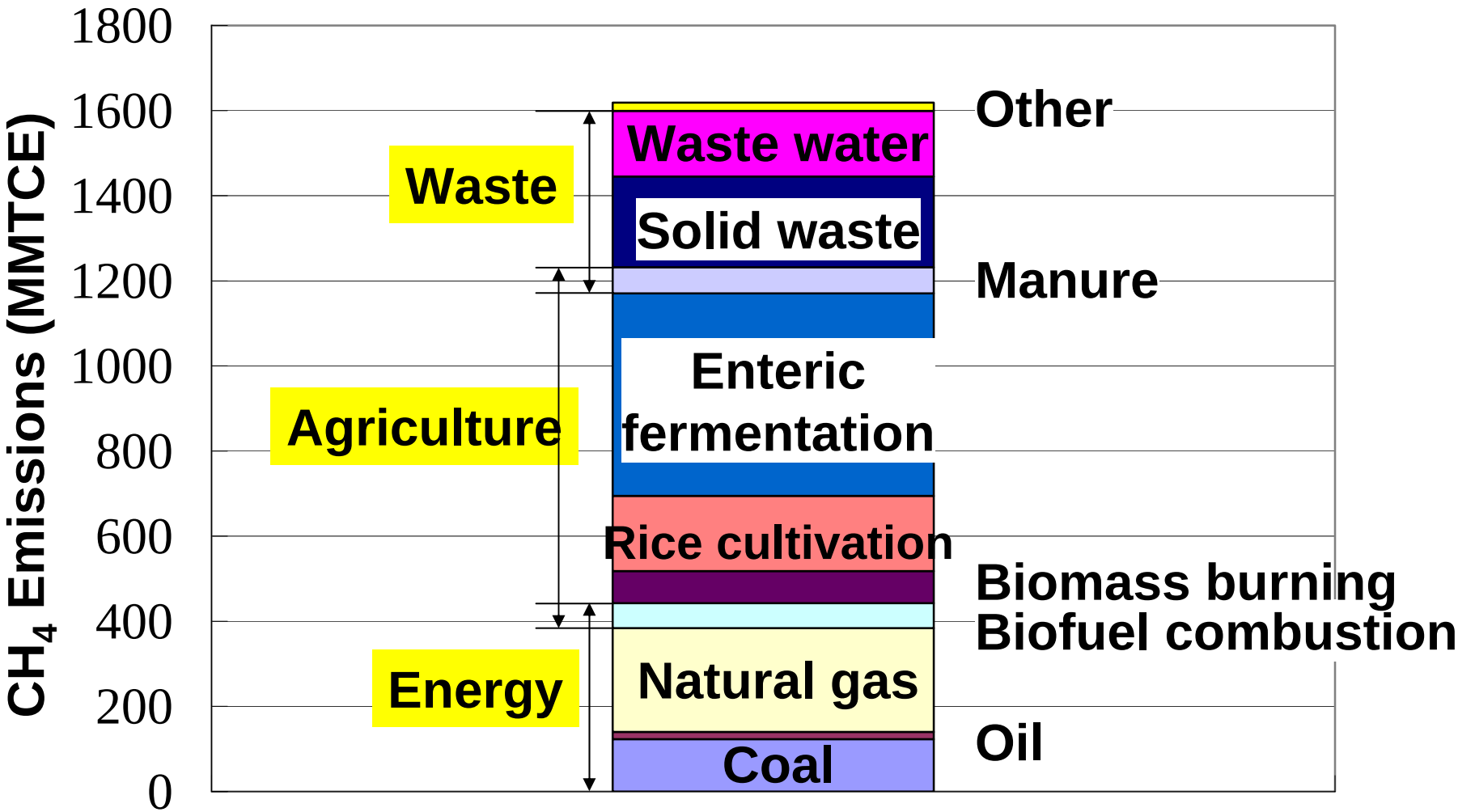
(MMTCE: Million Metric Ton Carbon Equivalent)

1997 GHG Emissions of selected countries



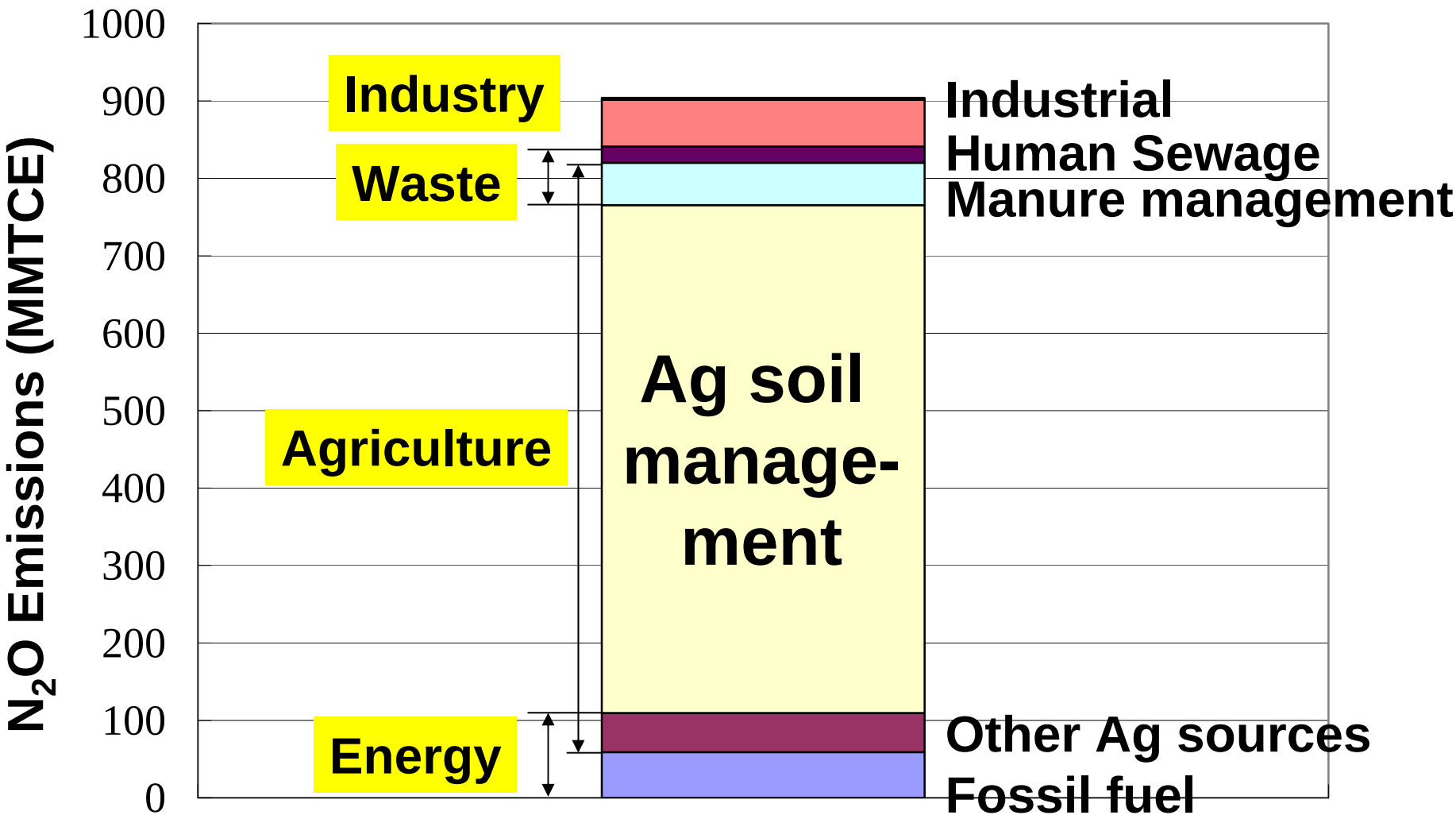
Data source: USEPA

Global CH_4 Emissions in 2000



Data source: USEPA

Global N_2O Emissions in 2000



Data source: USEPA

Why do we need multi-gas emission model?

- To estimate economic impact w/wo non-CO2 gas mitigation options for GHG stabilization scenarios

Economic model

- To analyze characteristics of non-CO2 gas abatement technologies and its potentials

Technology model

- To investigate the way both for reduction of GHG emissions and sustainable development

Integrated model

AIM model components for EMF21

- **AIM/CGE: Long-term scenario of Multi-gas**
  - Top-down economic global model
  - Recursive dynamics CGE model
  - Multi-regional, multi-sectoral, multi-gas model
- **AIM/Enduse: Detailed Sketch of Multi-gas**
  - Technology detailed country bottom-up model

Basic framework of AIM/CGE

- Type: Top-down, CGE, recursive dynamics
- Program：GTAP-EG/GAMS/MPSGE
- Database：GTAP ver.5(1997), IEA
- Target Year: 2100
- Target Region: 18 regions
- Target Sector: 13 sectors
- Energy depletion, electricity mix
- Non-CO_2 gas abatement
- (Land use: use SRES/B2(AIM) scenario)

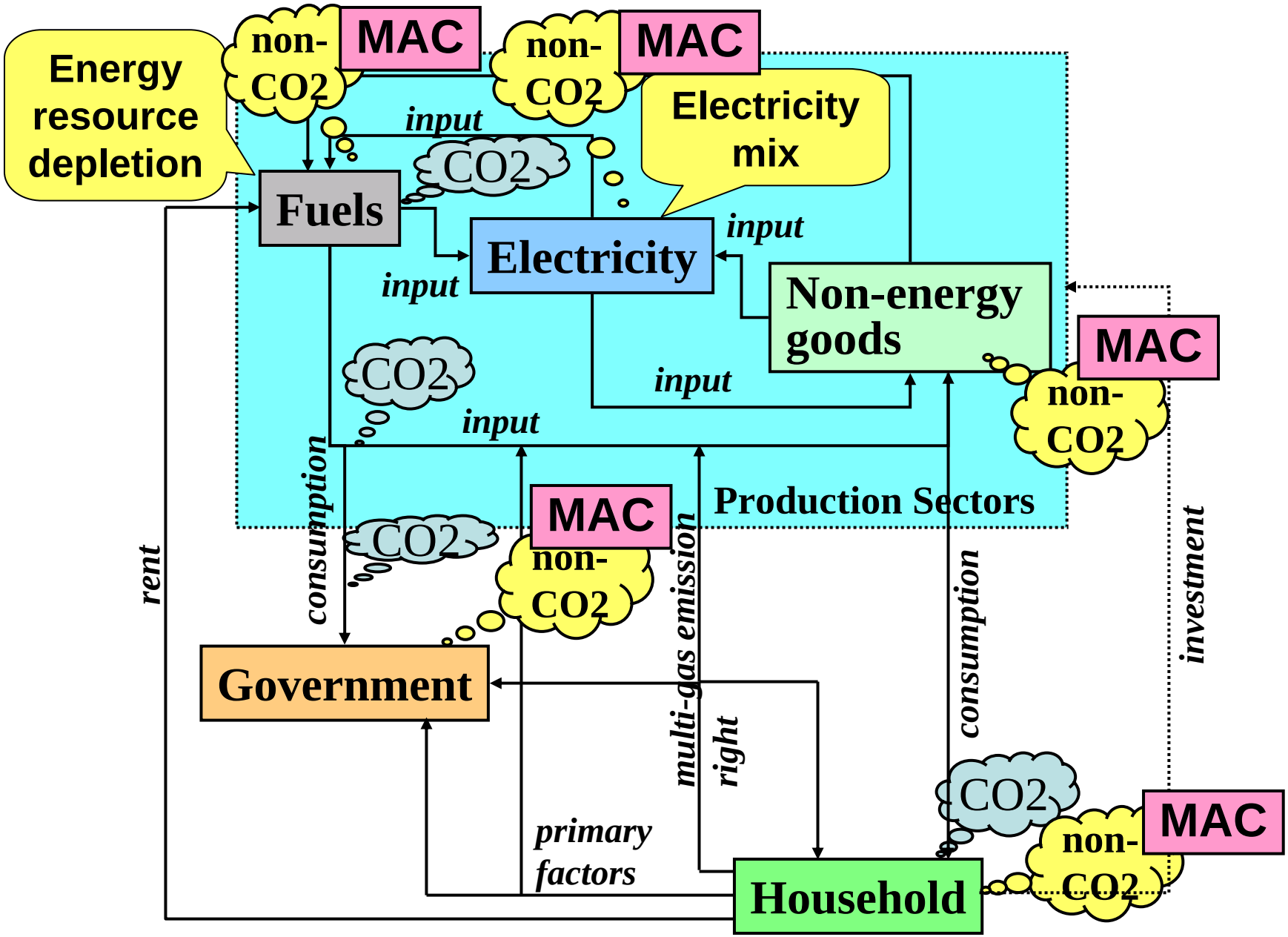
Regions of AIM/CGE

1	ANZ	Australia/NZ	10	OWE	Other Western Europe
2	JPN	Japan	11	EEU	Eastern Europe
3	KOR	Korea, Rep.	12	FSU	FSU
4	CHN	China	13	OPE	OPEC
5	IND	India	14	MEX	Mexico
6	SEA	South & SE Asia	15	BRA	Brazil
7	USA	USA	16	LAM	Latin America
8	CAN	Canada	17	AFR	Africa
9	WEU	EU15	18	ROW	Rest of the World

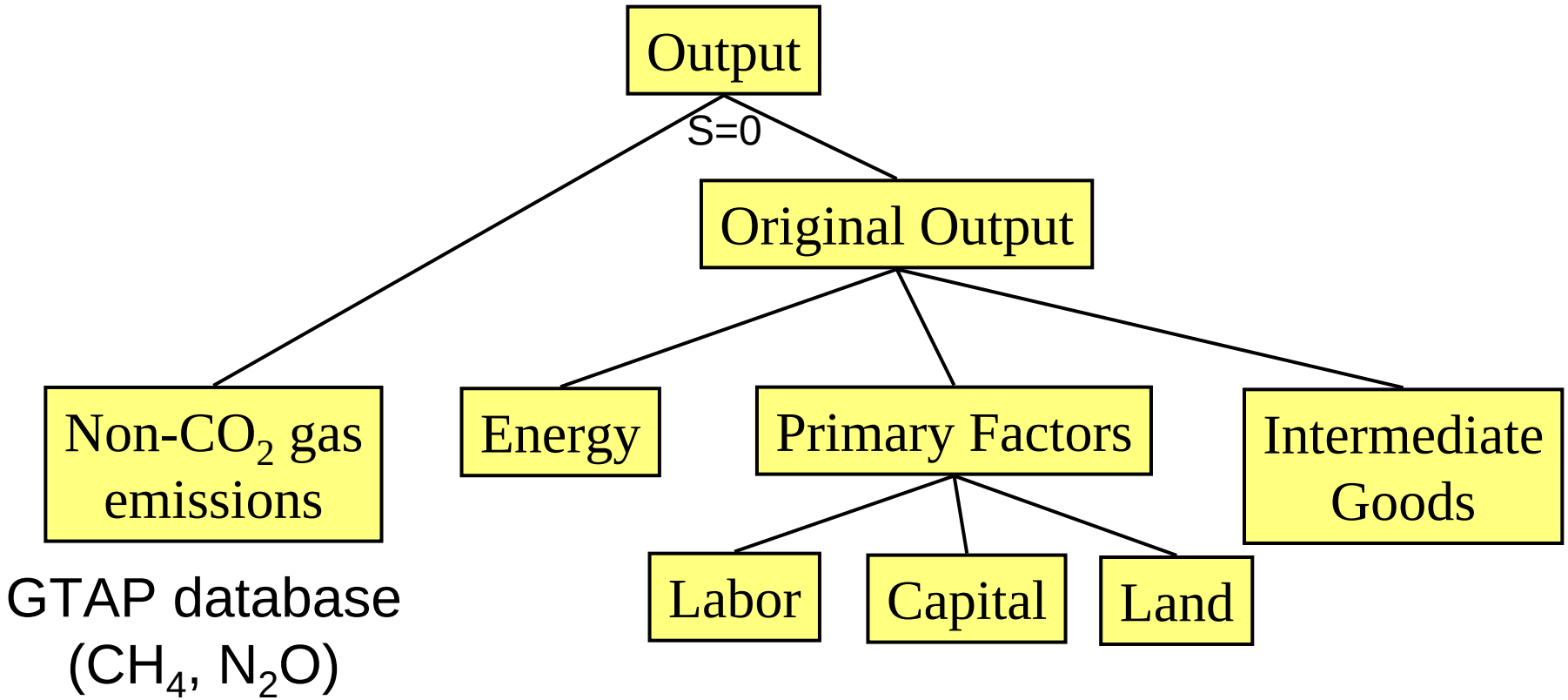
Sectors of AIM/CGE

1	GAS	Natural gas works	8	FRS	Forestry
2	ELE	Electricity and heat	9	FSH	Fishing
3	OIL	Refined oil products	10	EII	Energy Intensive Industry
4	COL	Coal transformation	11	OIN	Other Industry
5	CRU	Crude oil	12	T_T	Transport
6	AGR	Agriculture	13	SER	Service
7	LVK	Livestock			

Structure of AIM/CGE model



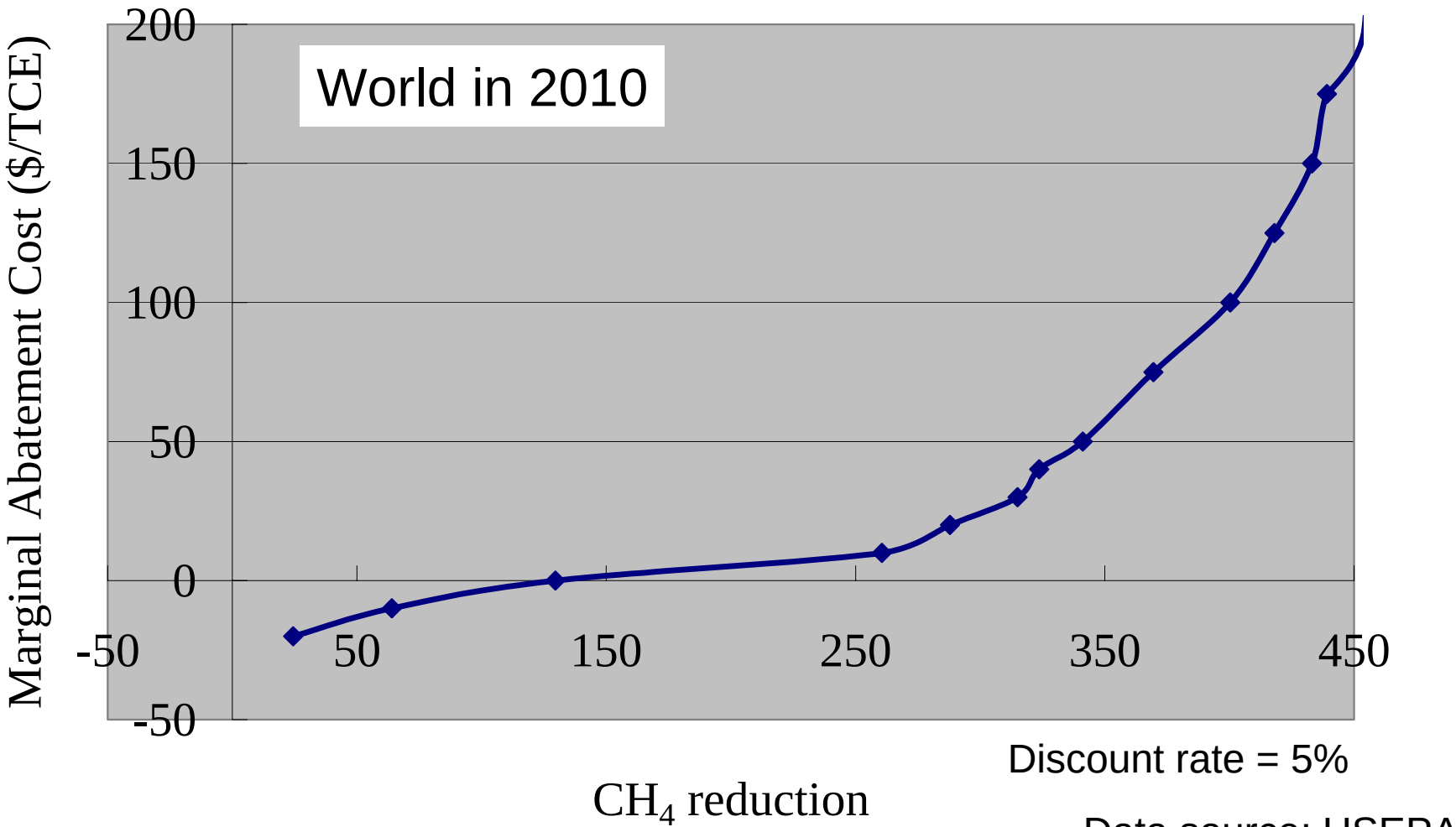
Non-CO_2 gas emissions



GTAP database
(CH_4, N_2O)

Top-level nest (s=0) is assumed for production sectors and final demand sector

Marginal Abatement Cost Curves (MACs) for CH_4



Data source: USEPA

Non-CO_2 gas MAC as CES function

Refer to R. C. Hyman, et al.; Modeling Non-CO2 Greenhouse Gas Abatement, MIT Joint Program on the Science and Policy of Global Change, Report No. 94 (2002).

$$\left(\frac{Y}{Y_0}\right)=\left\{a\left(\frac{X}{X_0}\right)^{-\rho}+(1-a)\left(\frac{Z}{Z_0}\right)^{-\rho}\right\}^{-\frac{1}{\rho}}$$

X: non-CO_2 gas emission Z: Original Output

Y: Modified Output with non-CO_2 gas emission

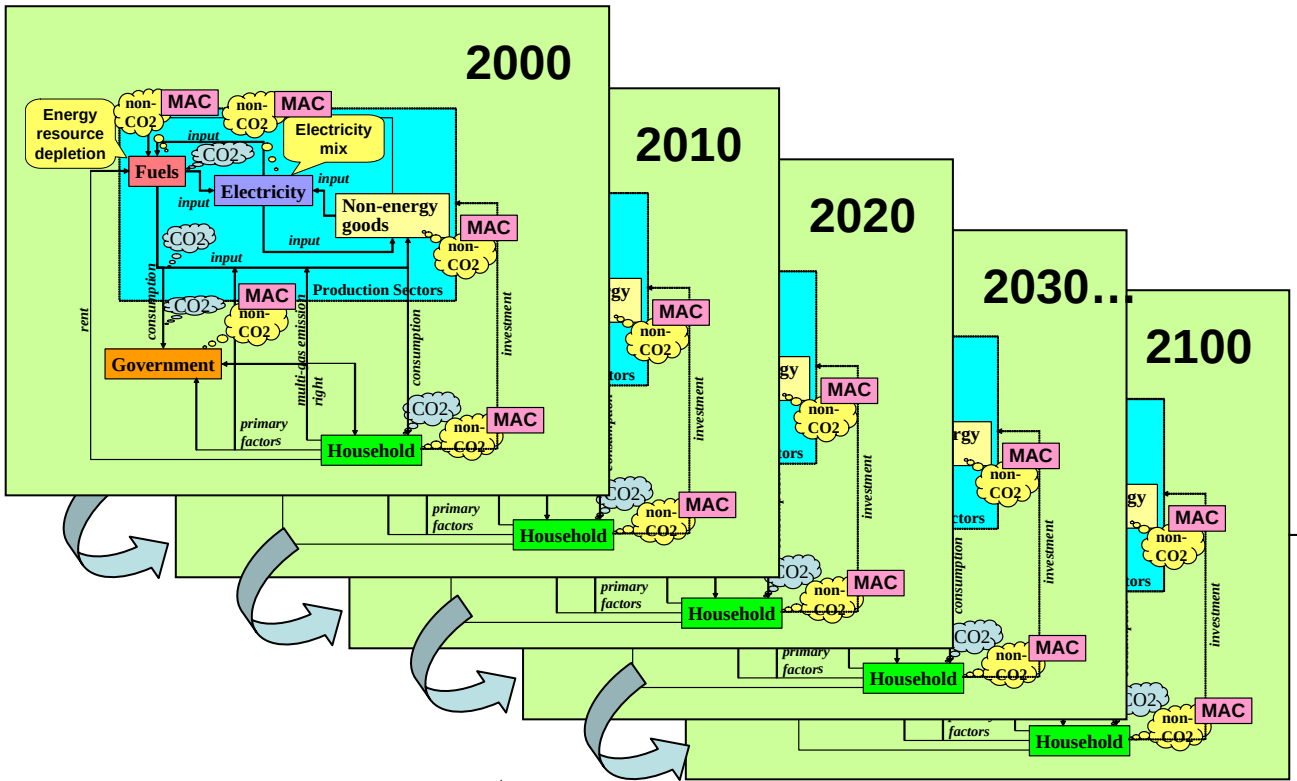
X_0, Y_0, Z_0: emission, output at base year

a：cost share for non-CO_2 gas abatement

ρ：substitution parameter between non-CO_2 gas(X) and original output(Z) (substitution elasticity $\sigma=\frac{1}{1+\rho}$)

Need more parameter adjustment of “a” and “**ρ**”

Radiative Forcing/Temperature raise constraint and dynamic recursive model



GHG emissions

Other gases:
SOx, NOx
BB+FF

Emission path to satisfy stabilization target

Simple Climate Model Based on Bern model (AIM/SSG)

EMF21 scenarios for long-term model

(1) BaU Modeler's reference (B2-like)

---

(2) Long-term stabilization scenarios

Stabilize radiative forcing at 4.5 W/m^2 by 2150 relative to pre-Industrial times

(2-1) CO_2 only (2-2) multi gas

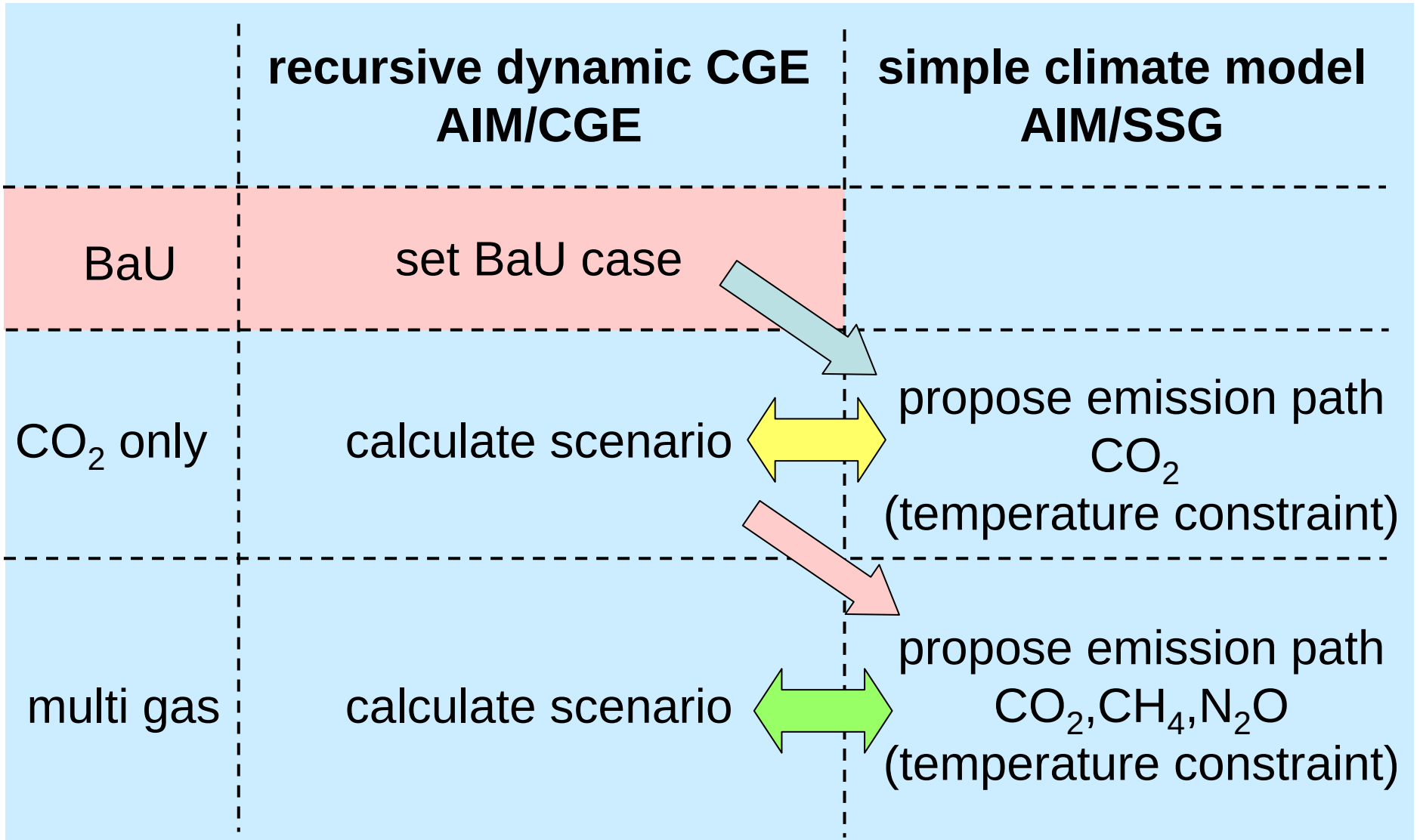
---

(3) Long-term stabilization scenarios with rate of temperature change

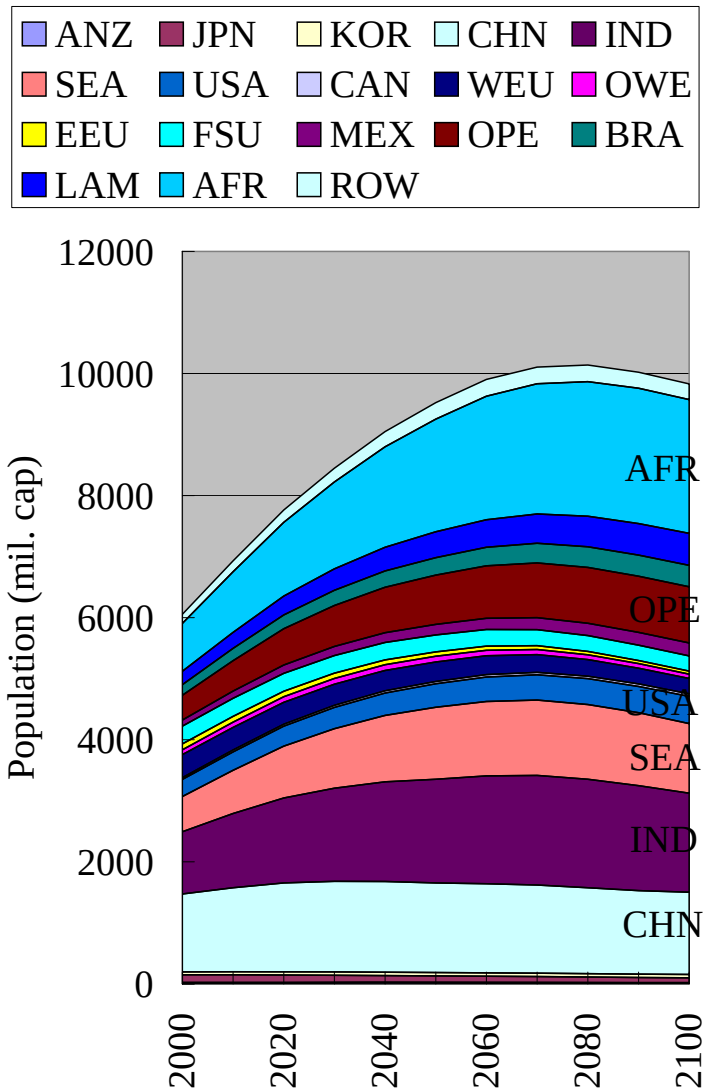
global mean temperature change to an average decadal rate of 0.20ºC

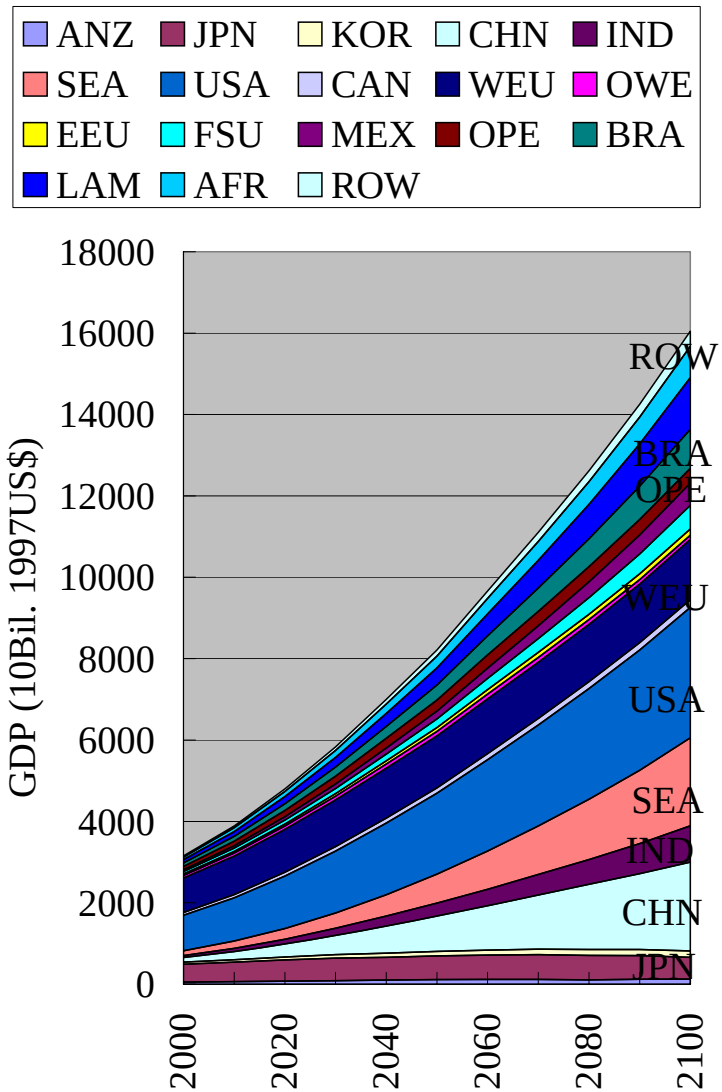
(3-1) CO_2 only (3-2) multi gas

Calculation flow with AIM models

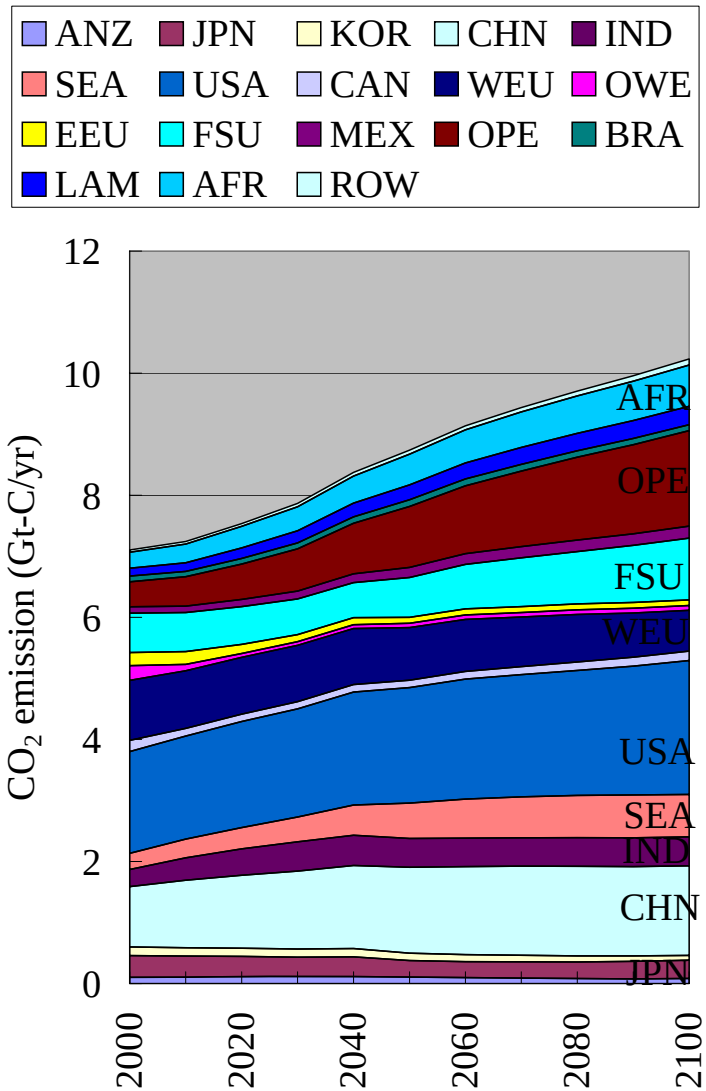


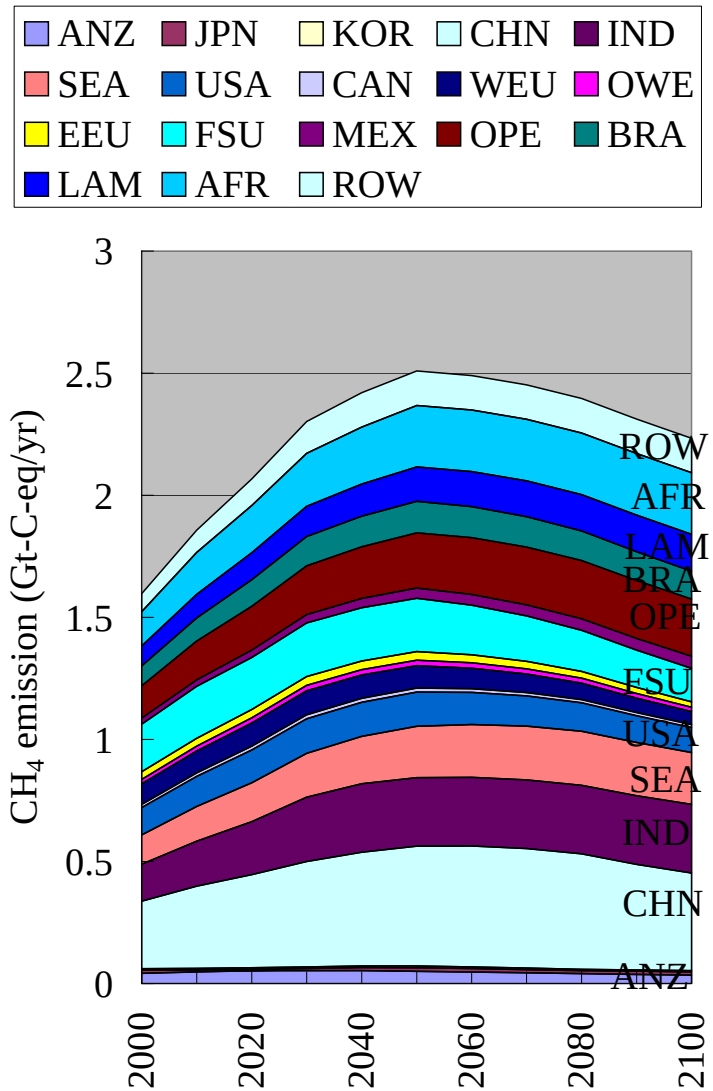
Population, GDP (BaU)



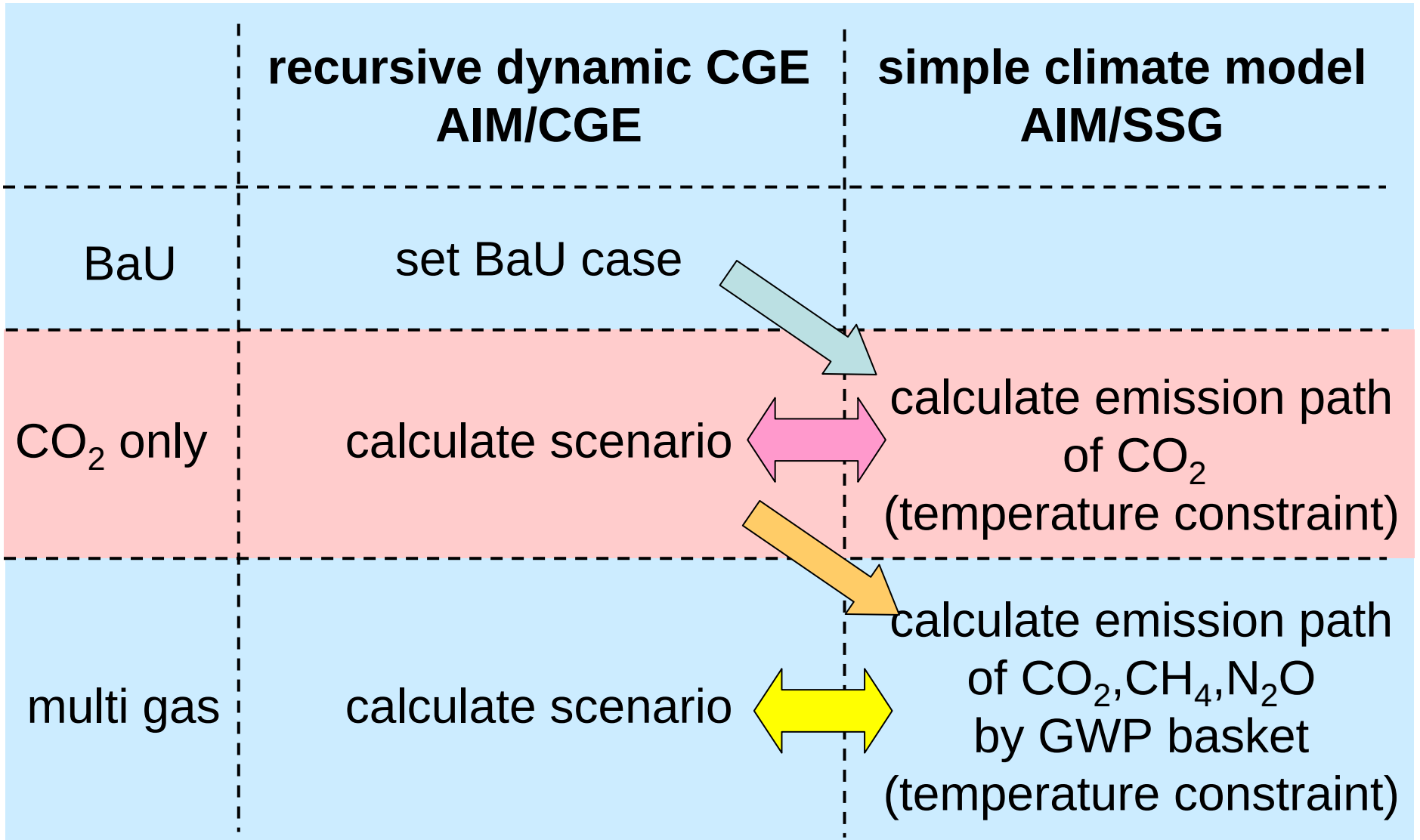


CO_2, CH_4 emission (BaU)

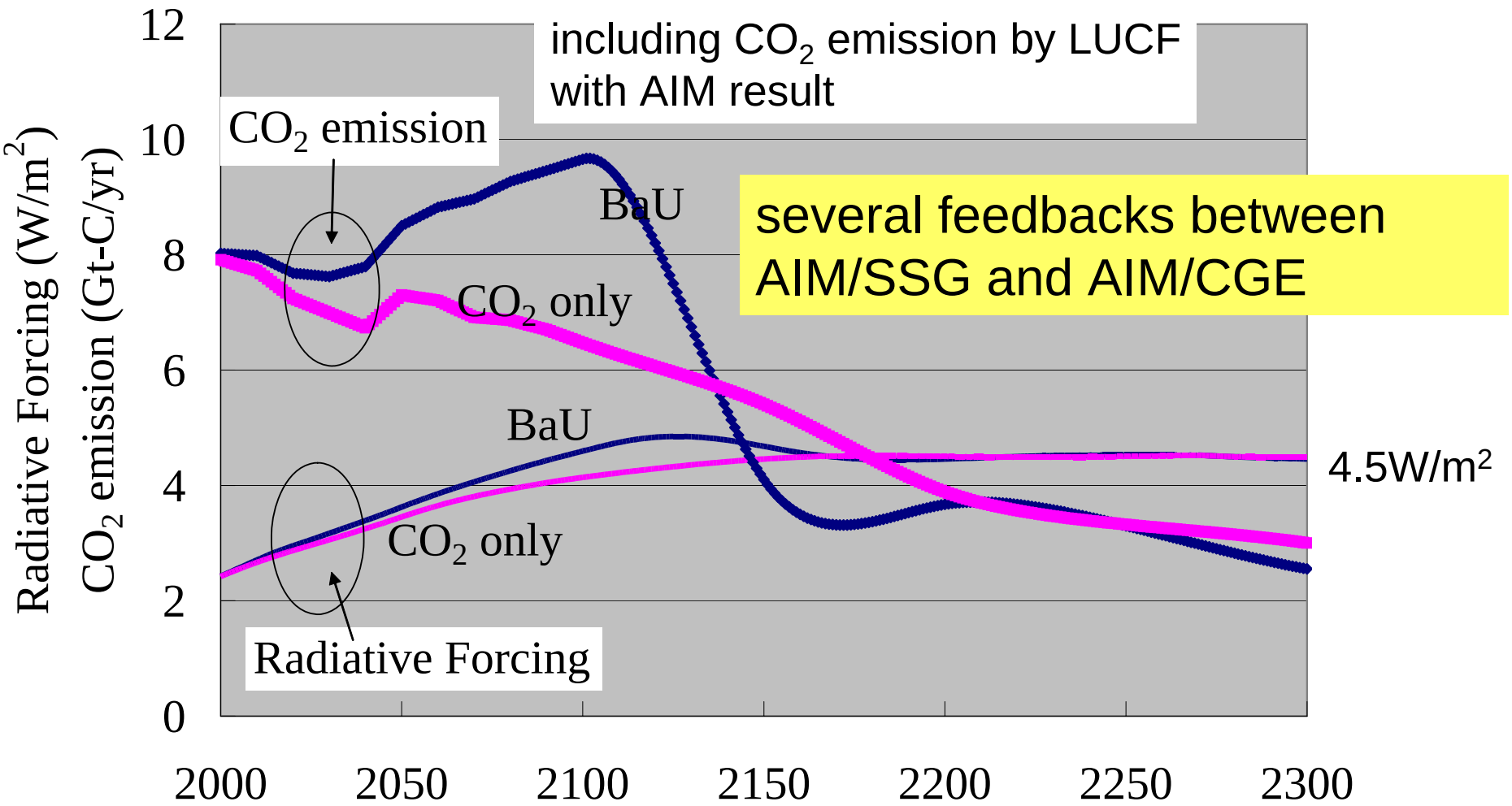




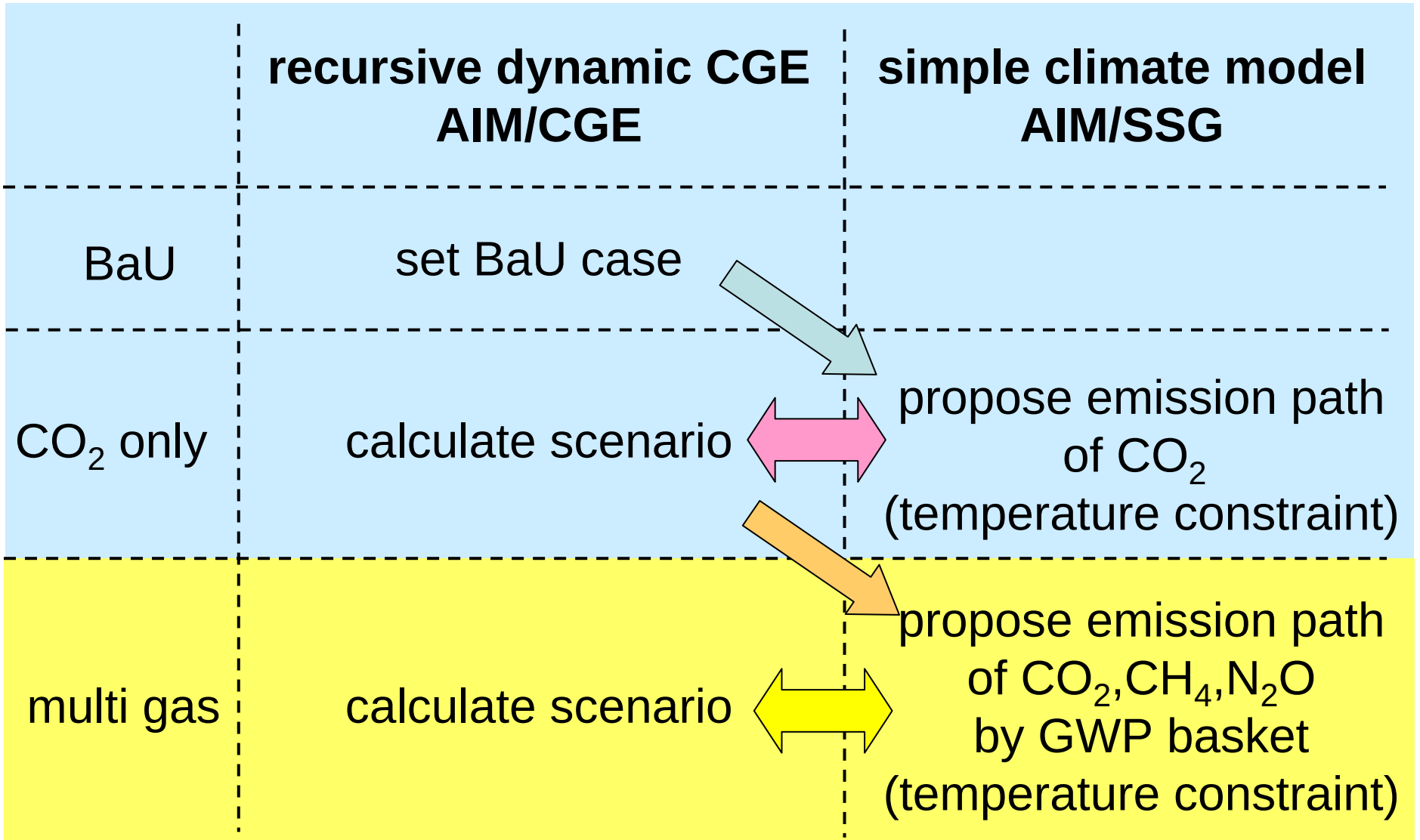
Calculation flow with AIM models



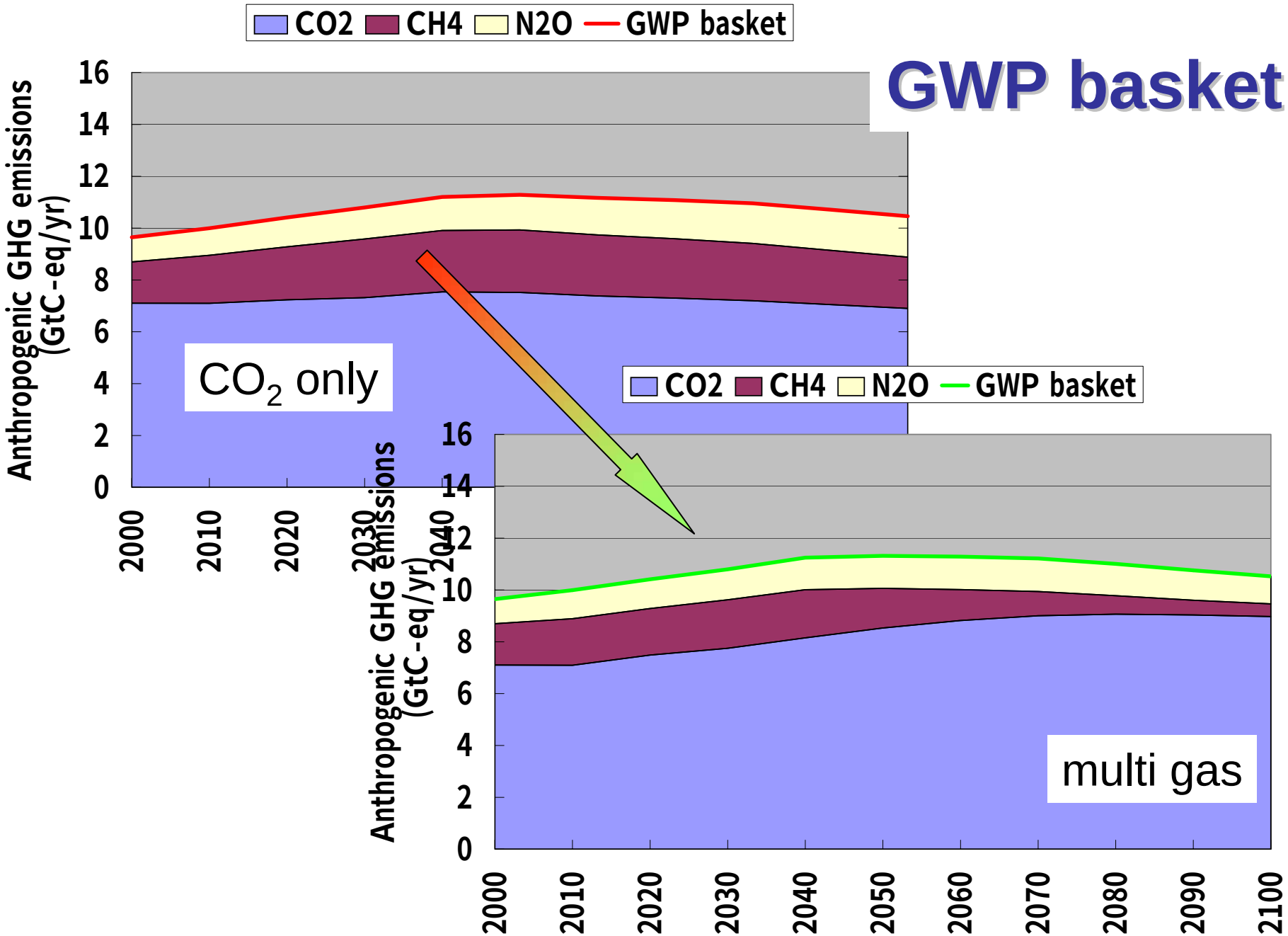
Calculate emission path by AIM/SSG : CO_2 only case



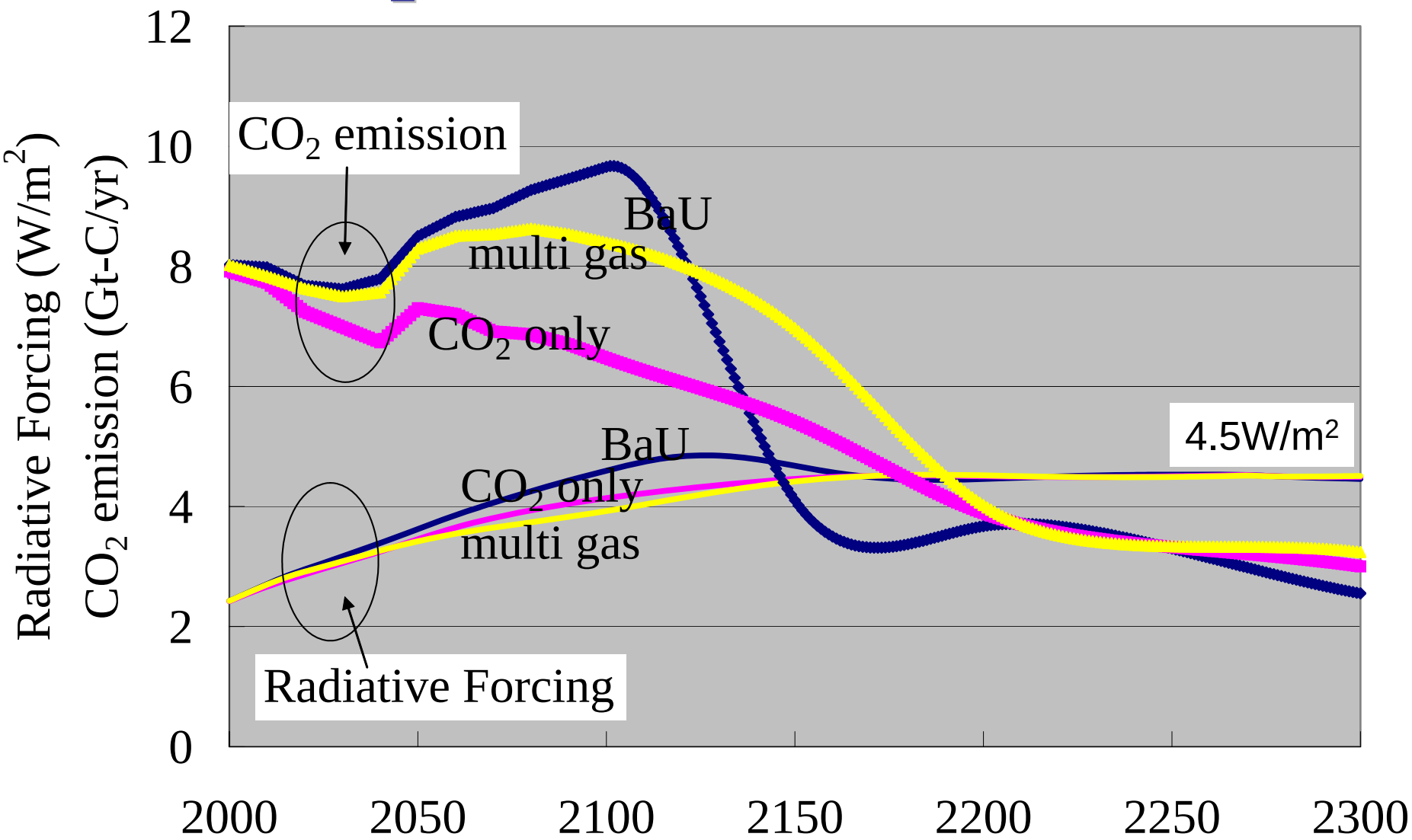
Calculation flow with AIM models



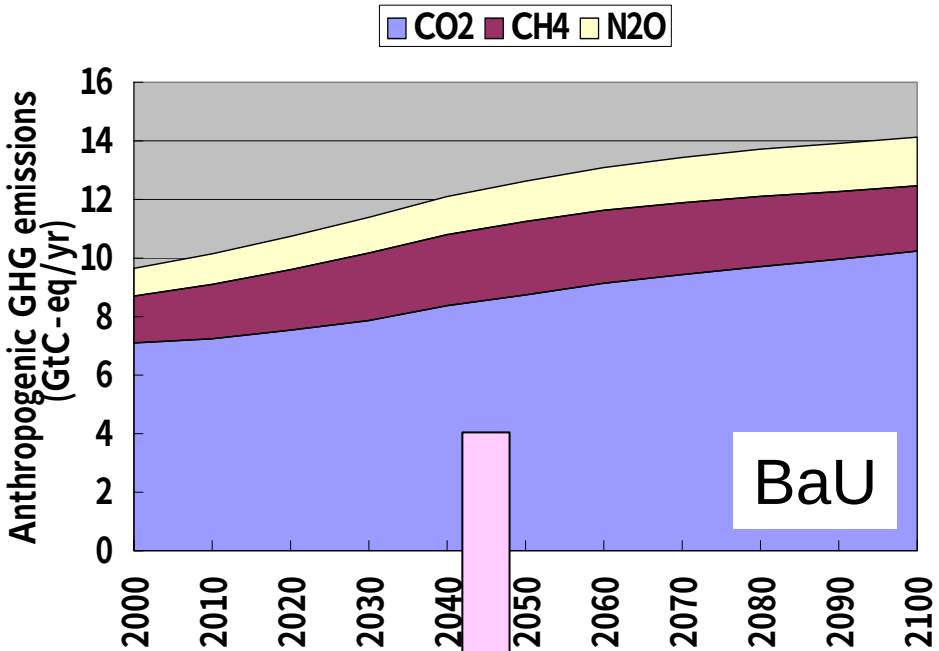
GWP basket

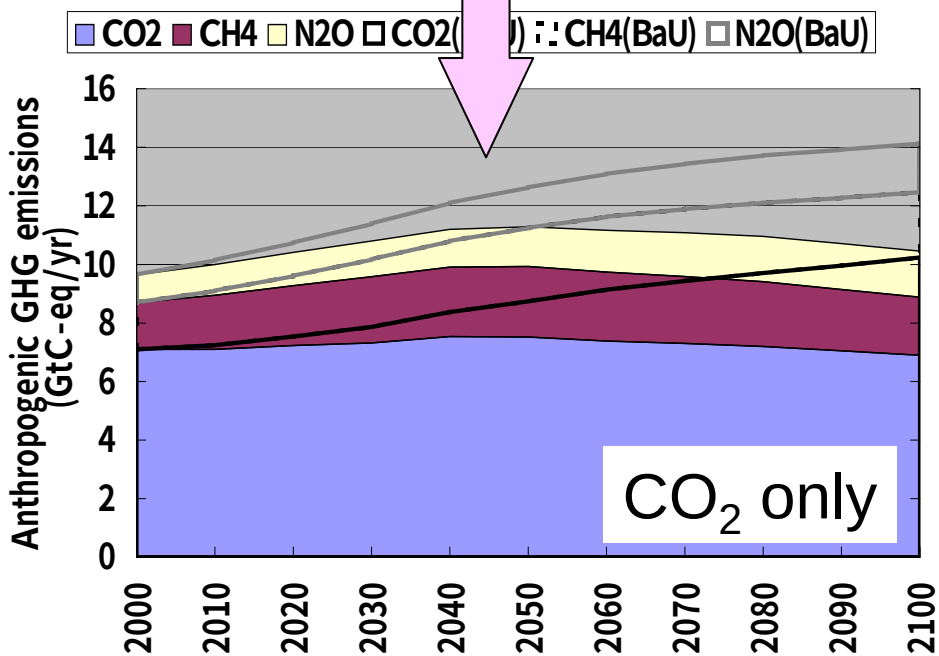

CO2
CH4
N2O
GWP basket
Anthropogenic GHG emissions (GtC-eq/yr)
0
2
4
6
8
10
12
14
16
2000
2010
2020
2030
2040
CO_2 only
CO2
CH4
N2O
GWP basket
Anthropogenic GHG emissions (GtC-eq/yr)
0
2
4
6
8
10
12
14
16
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
multi gas

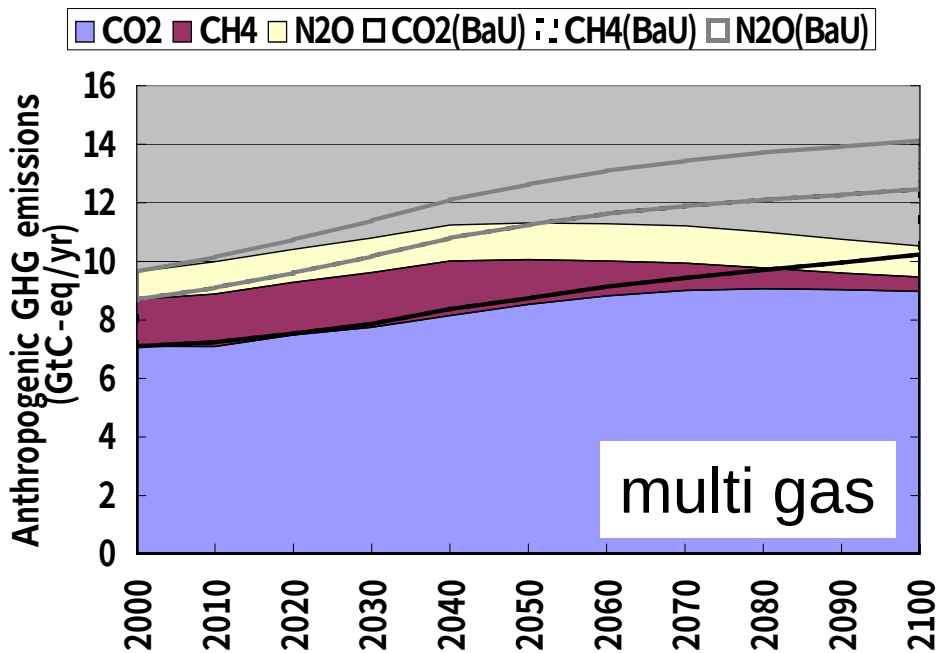
Radiative forcing and future CO_2 emission for stabilization



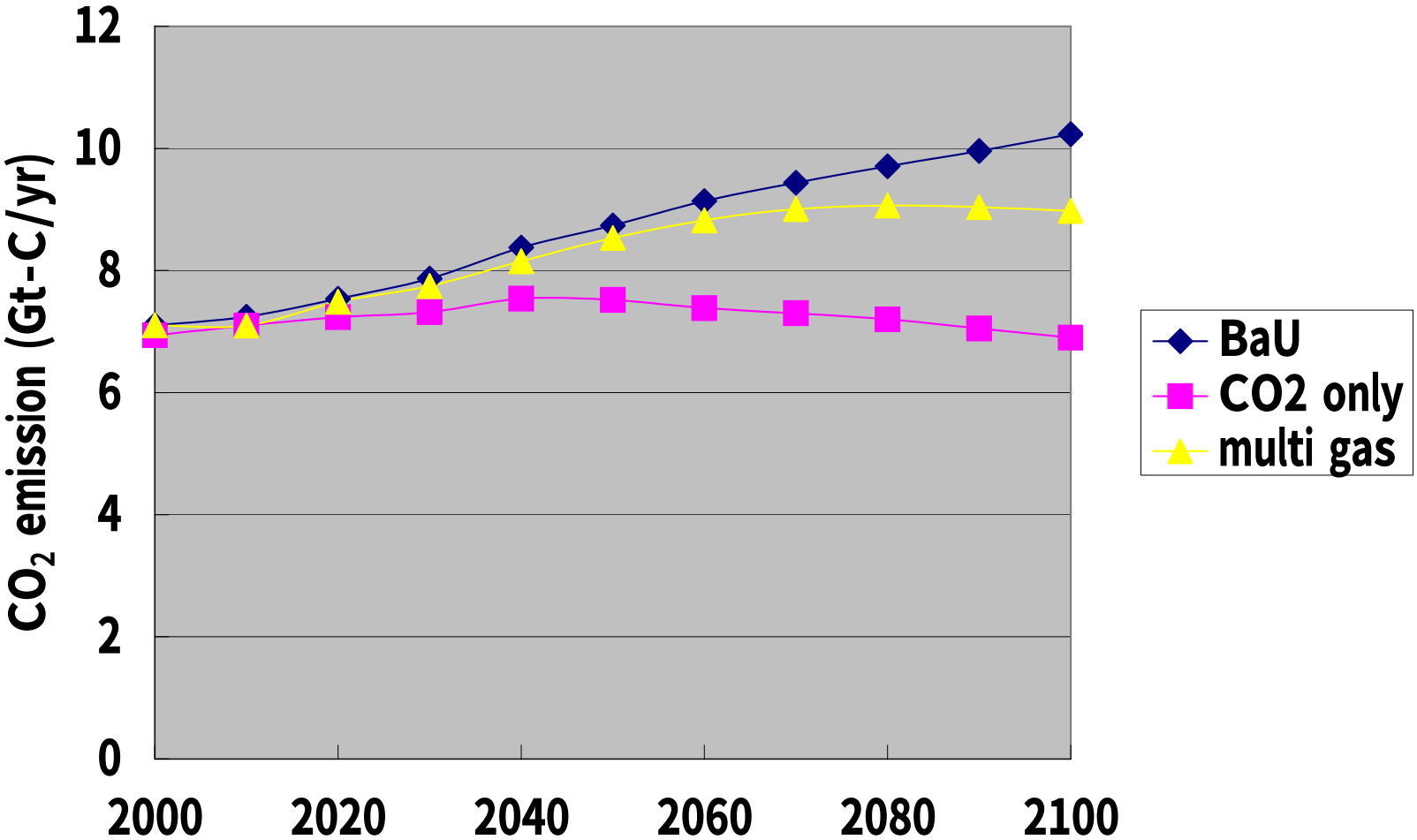
Anthropogenic GHG emissions



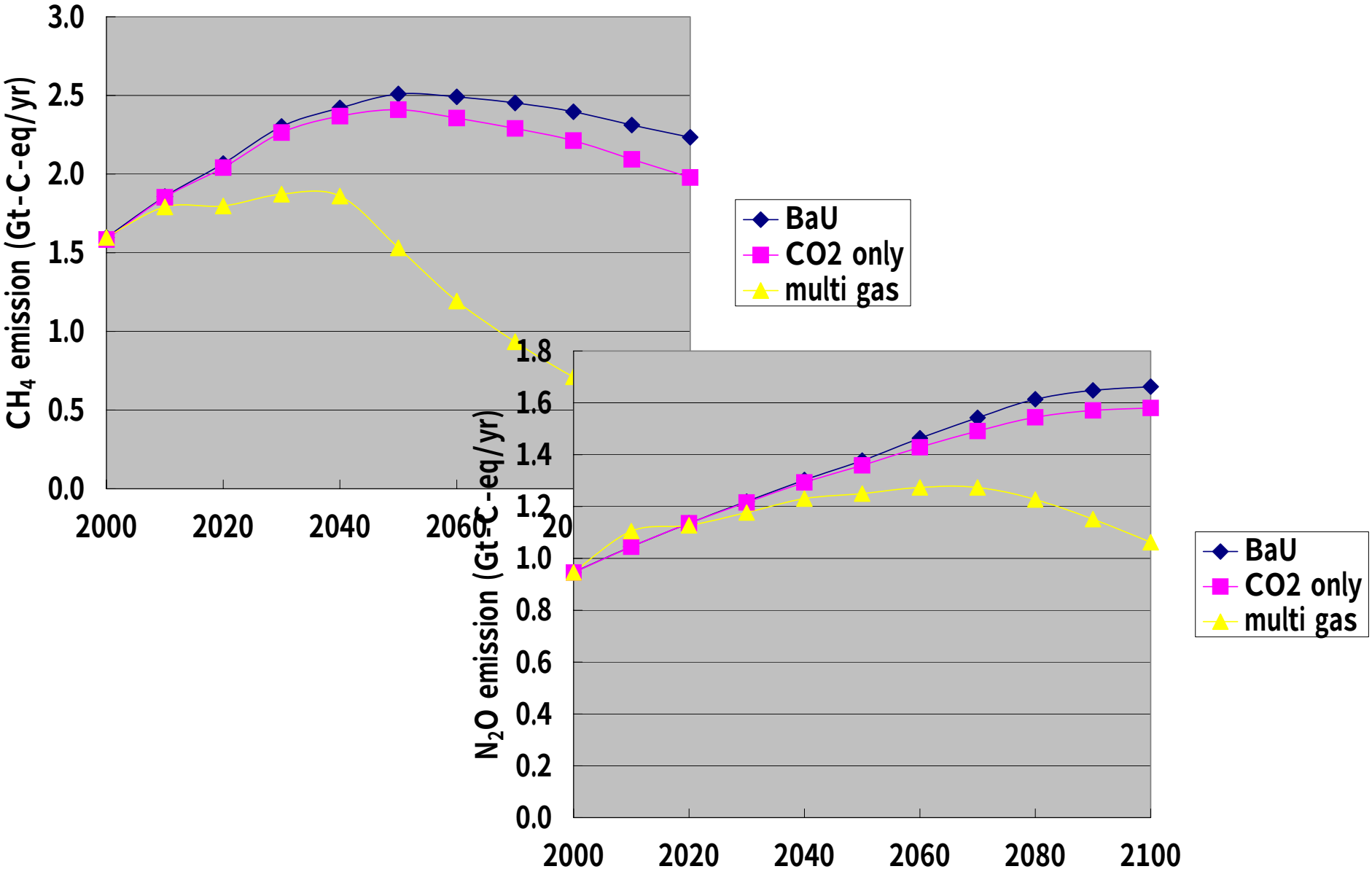




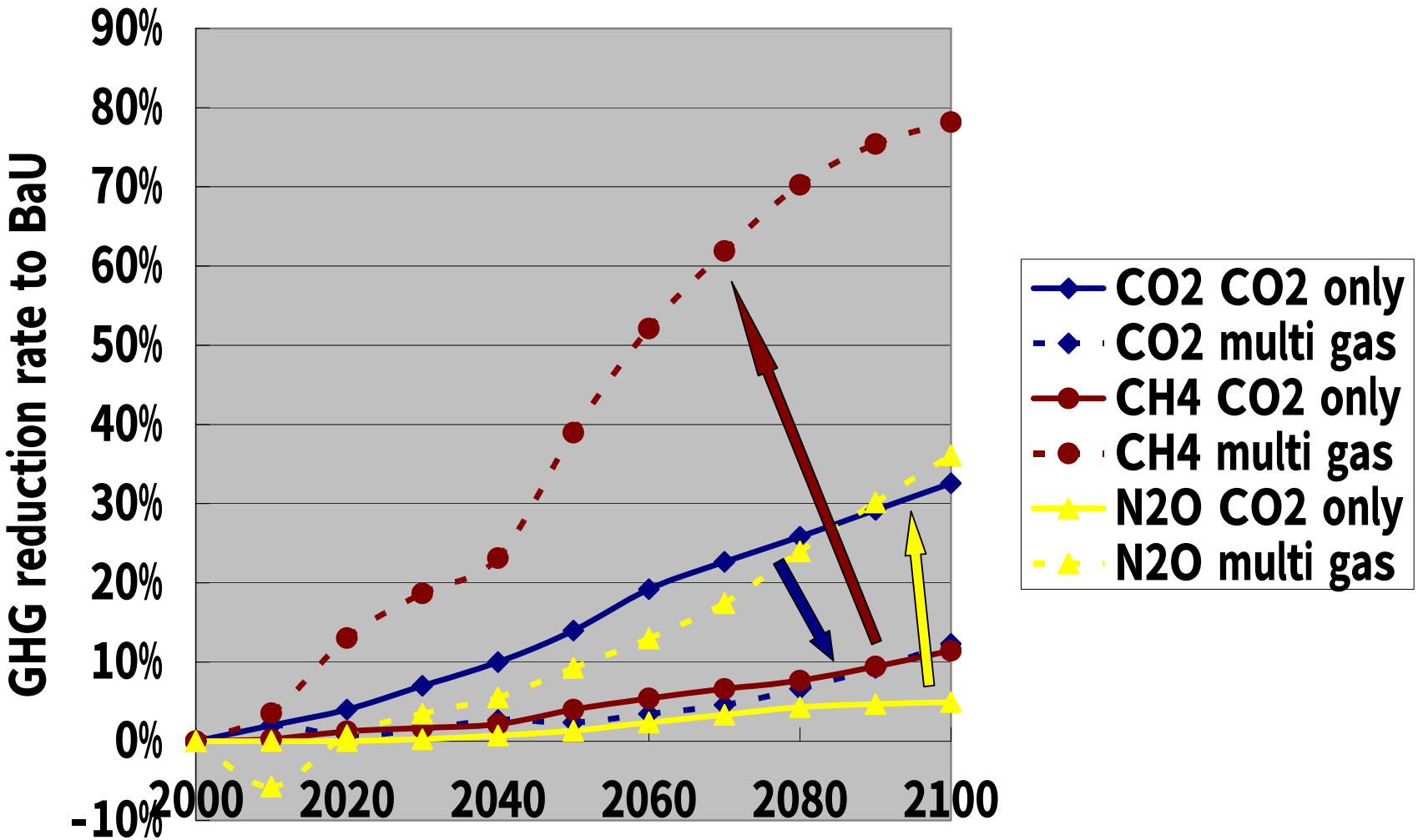
Anthropogenic CO_2 emission



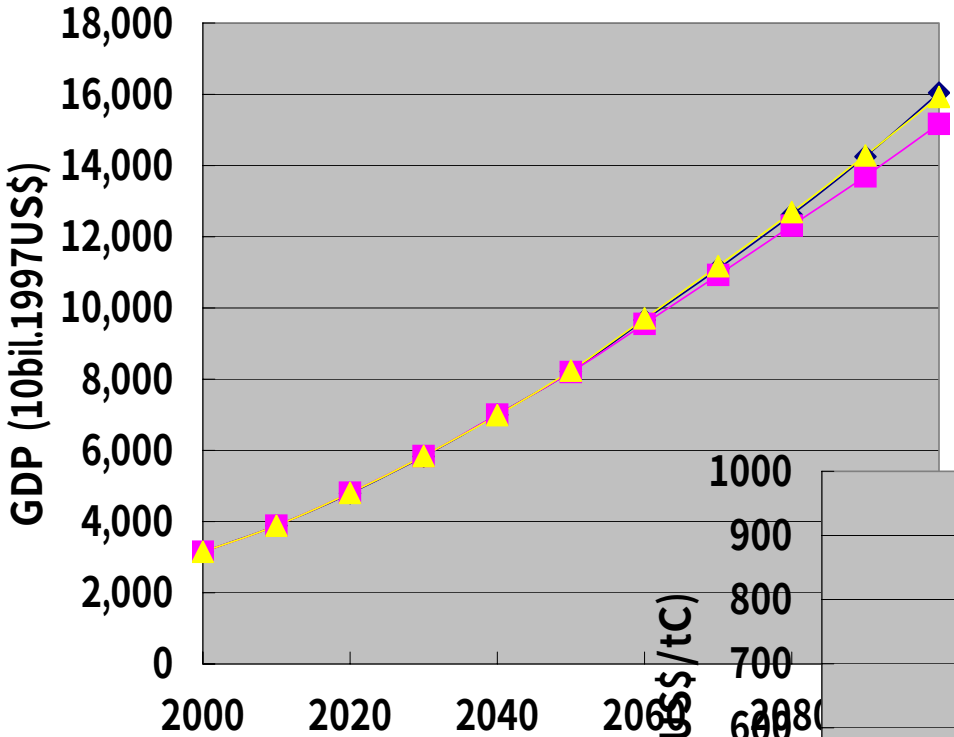
Anthropogenic CH_4 and N_2O emission

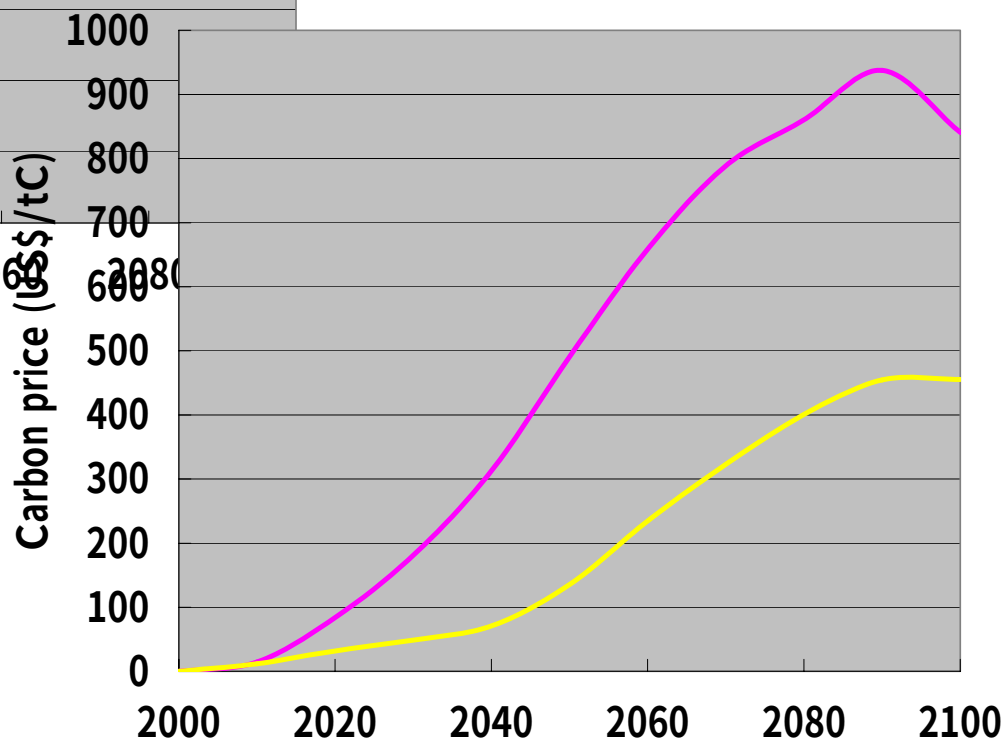


GHG reduction rate

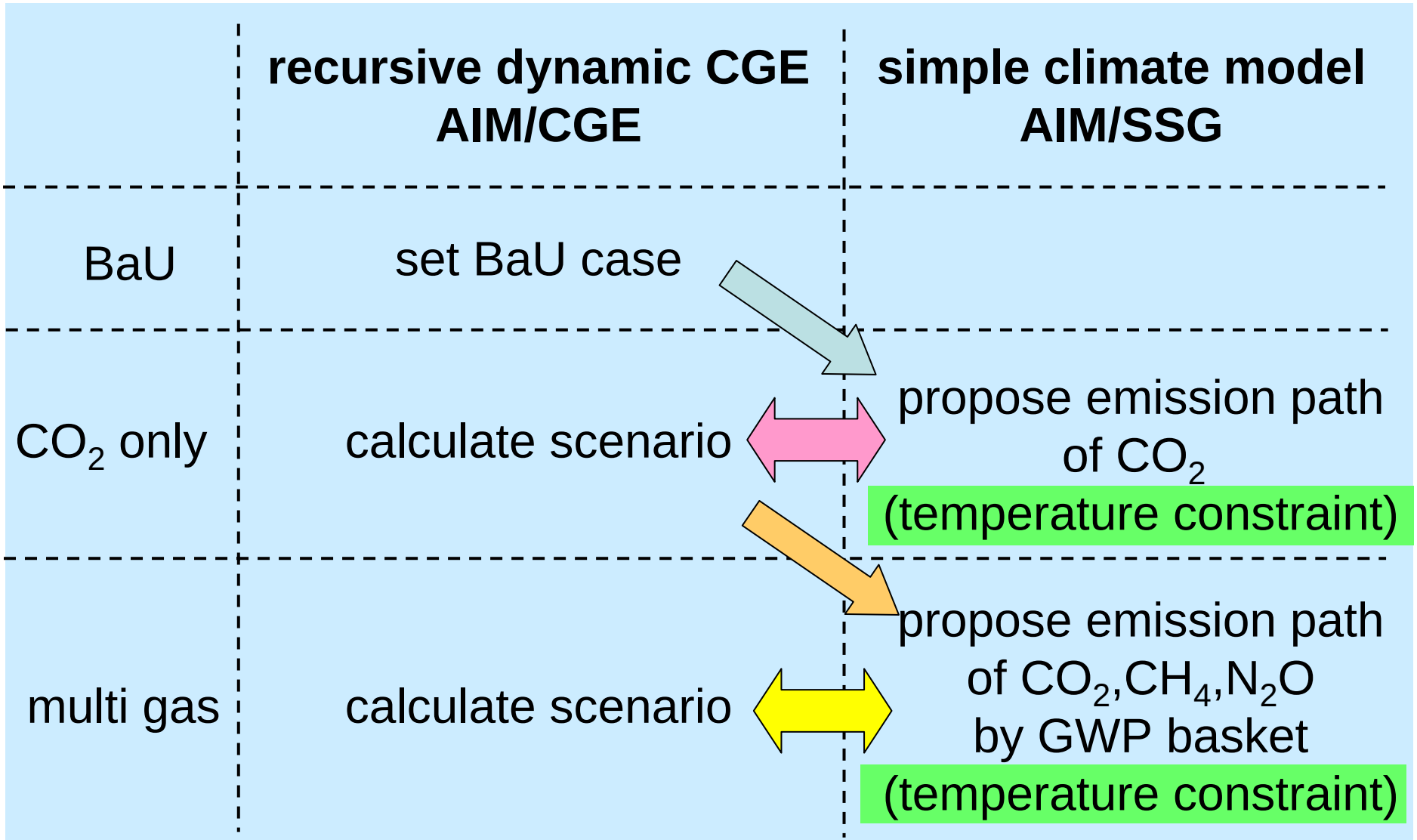


Economic impact

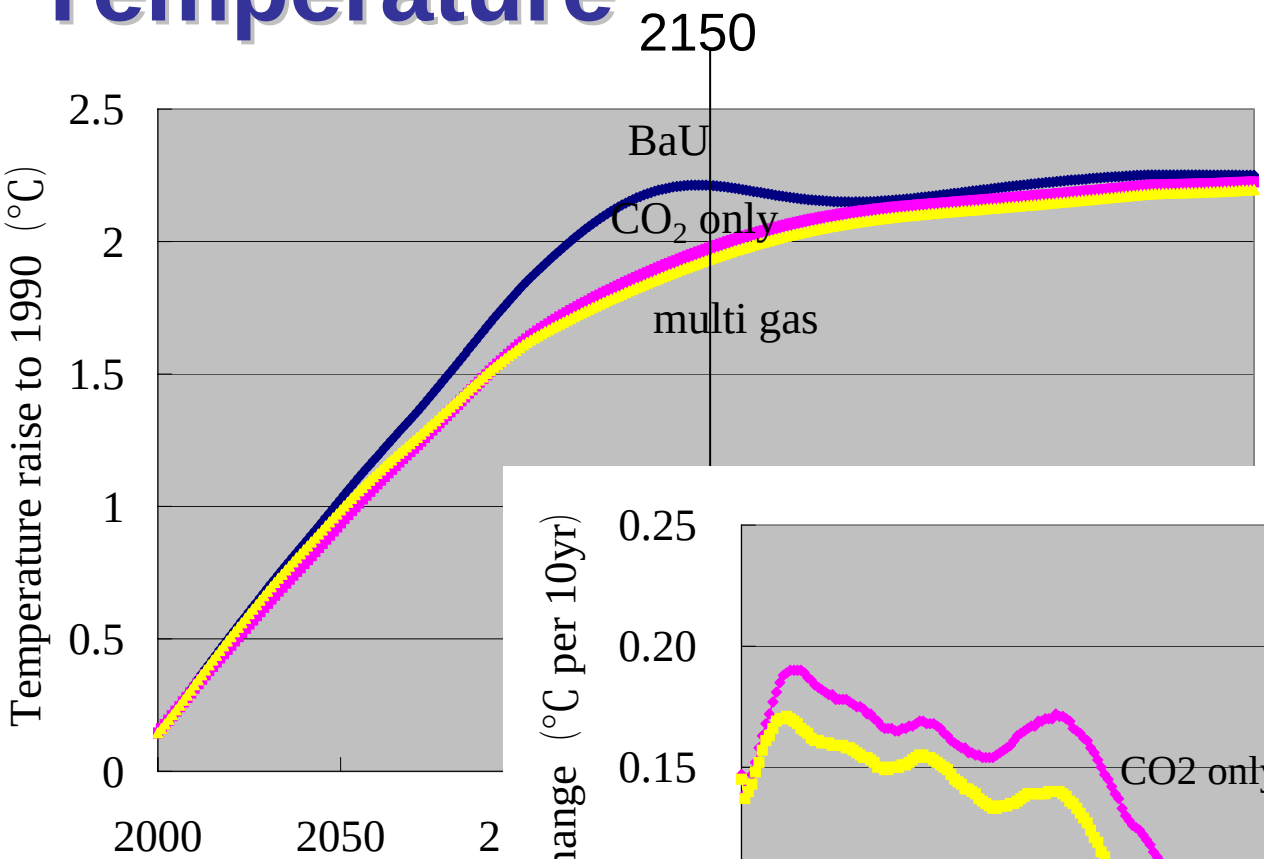


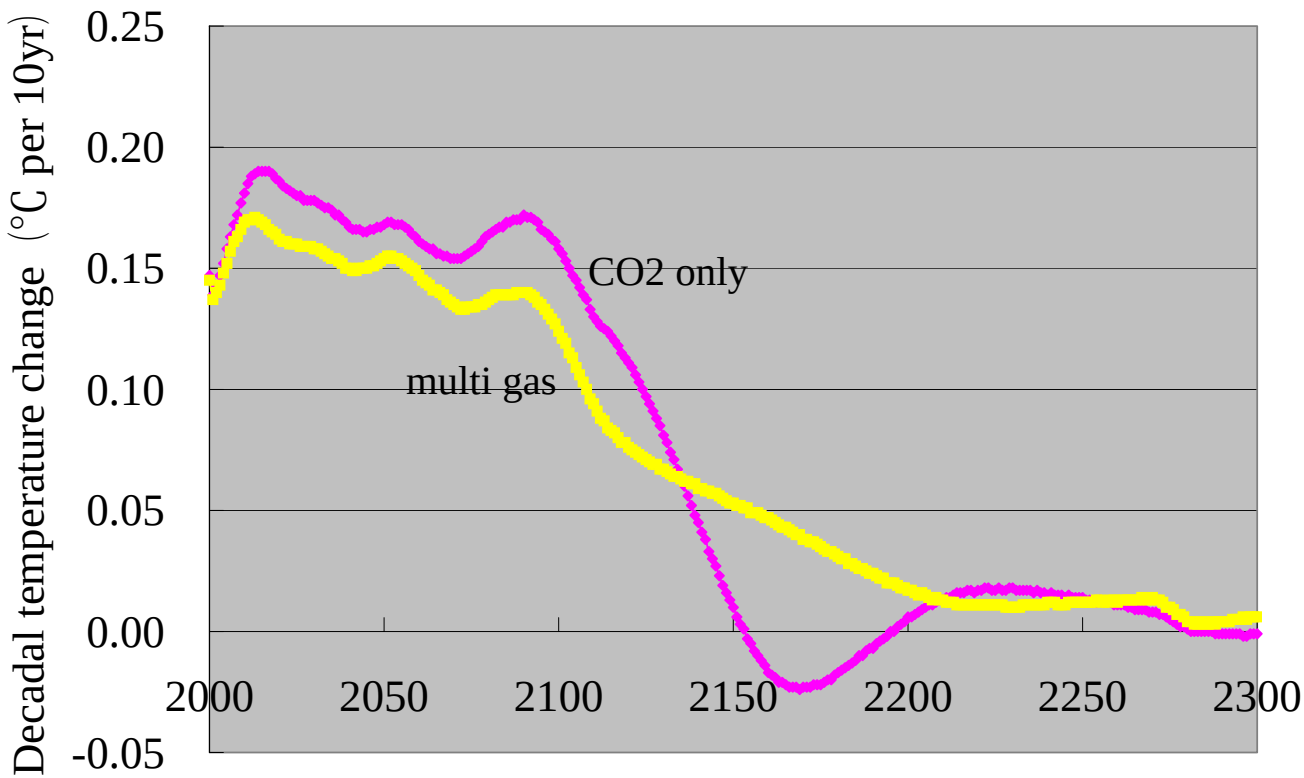


Calculation flow with AIM models

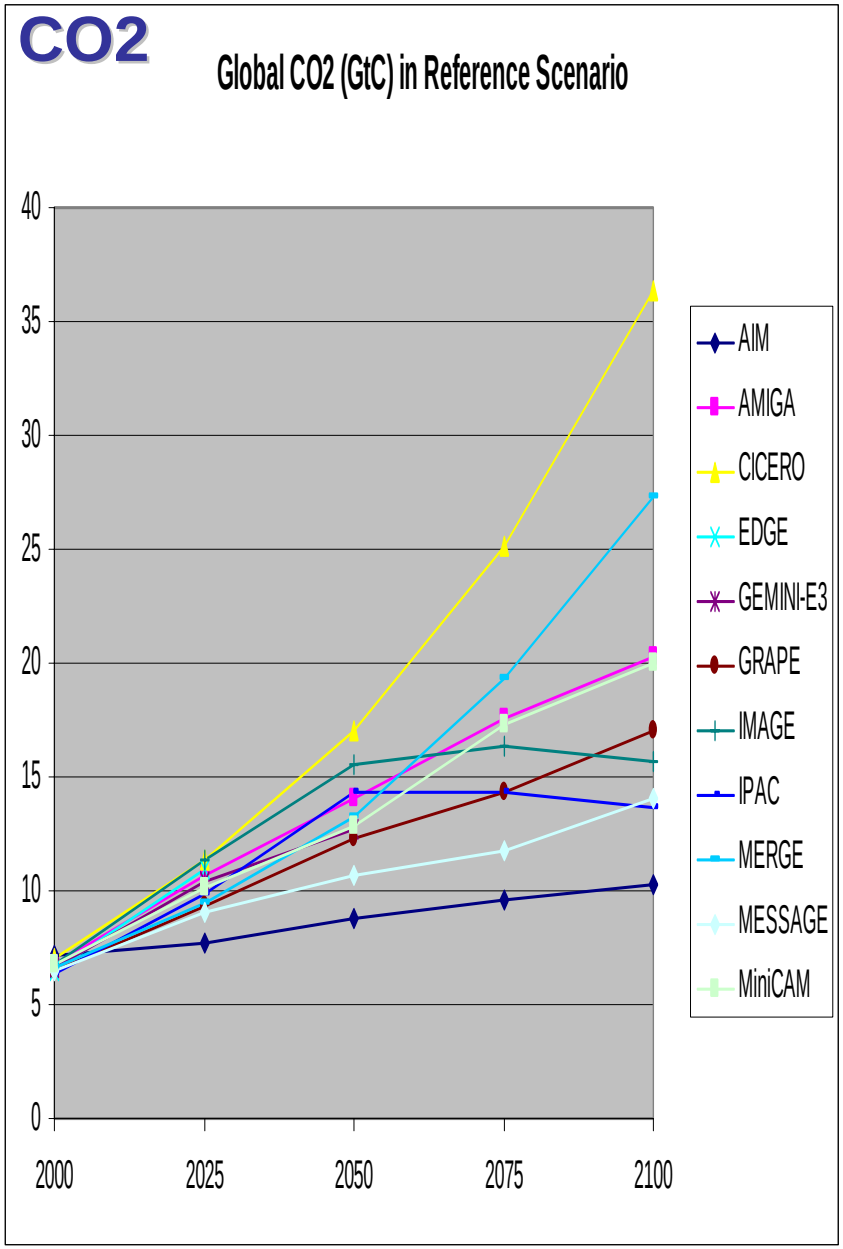


Temperature

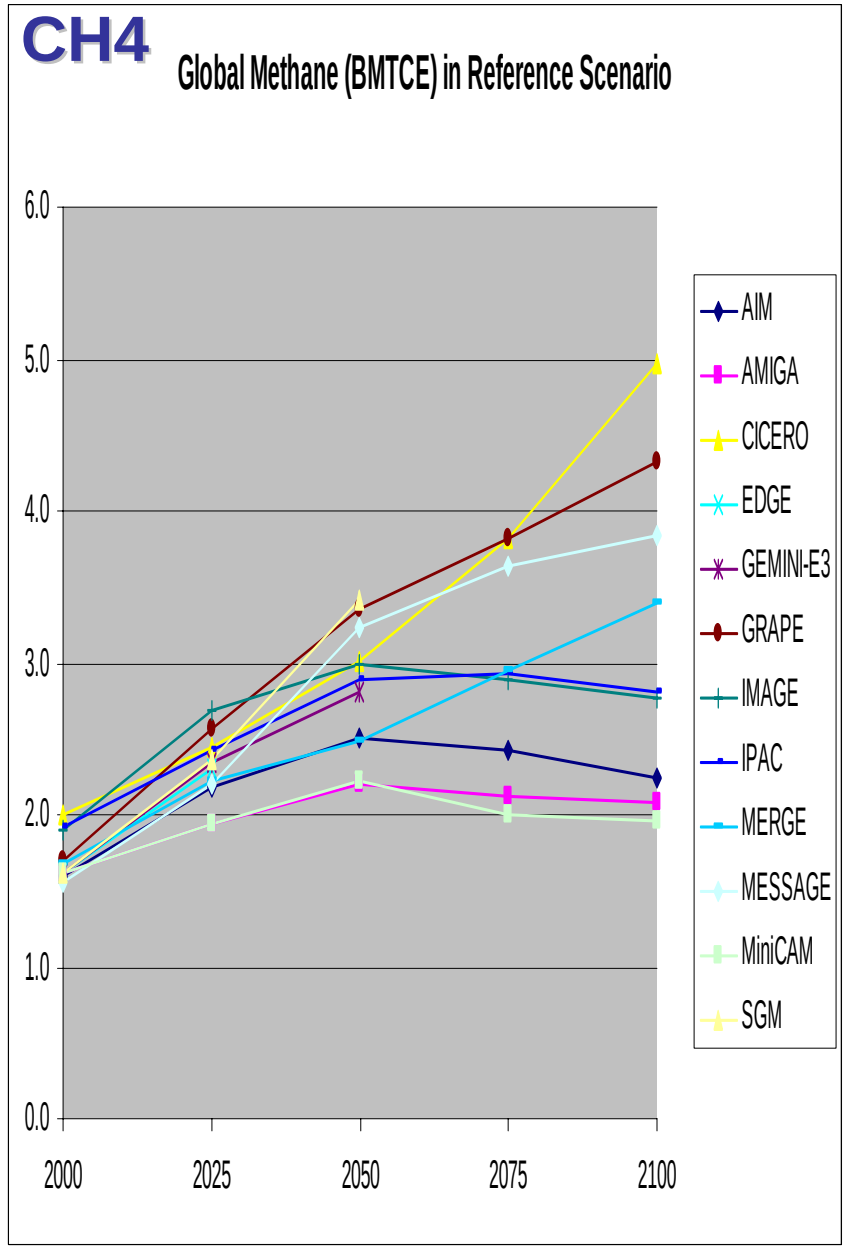




CO2


Global CO2 (GtC) in Reference Scenario
40
35
30
25
20
15
10
5
0
2000
2025
2050
2075
2100
AIM
AMIGA
CICERO
EDGE
GEMINI-E3
GRAPE
IMAGE
IPAC
MERGE
MESSAGE
MiniCAM

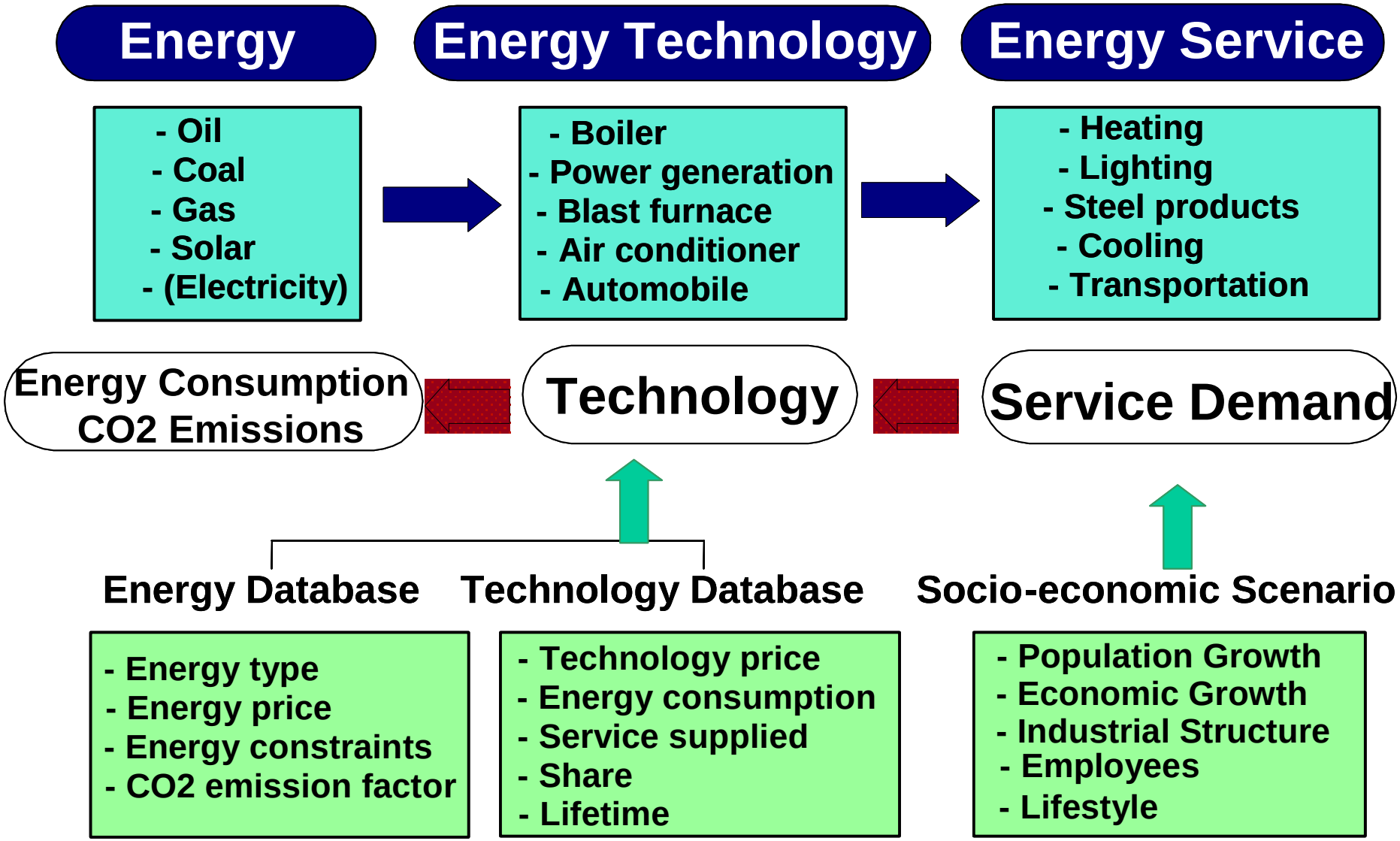
CH4


Global Methane (BMTCE) in Reference Scenario
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2000
2025
2050
2075
2100
AIM
AMIGA
CICERO
EDGE
GEMINI-E3
GRAPE
IMAGE
IPAC
MERGE
MESSAGE
MiniCAM
SGM

Bottom Up Modeling Approach for Non CO2 Gases: An Overview

Bottom Up analysis using the AIM/Enduse model

- AIM/Enduse models energy and materials through detailed representation of technologies
- Based on a linear optimization framework where system cost is minimized under several demand and supply constraints
- The model is being structured to include Non CO2 gas emission sectors and linking to removal processes



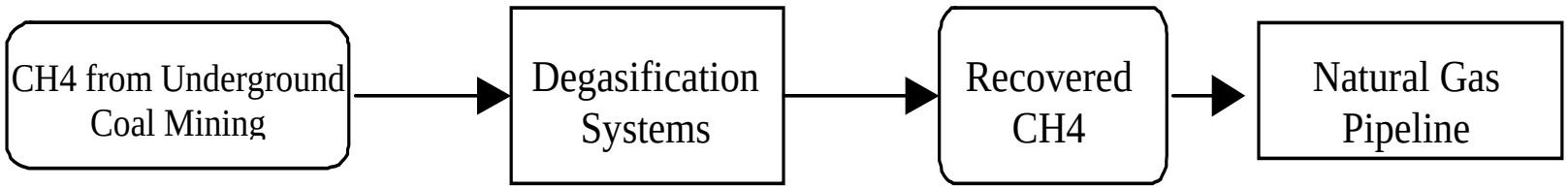
Framework of the AIM/Enduse Model

Methane abatement options example

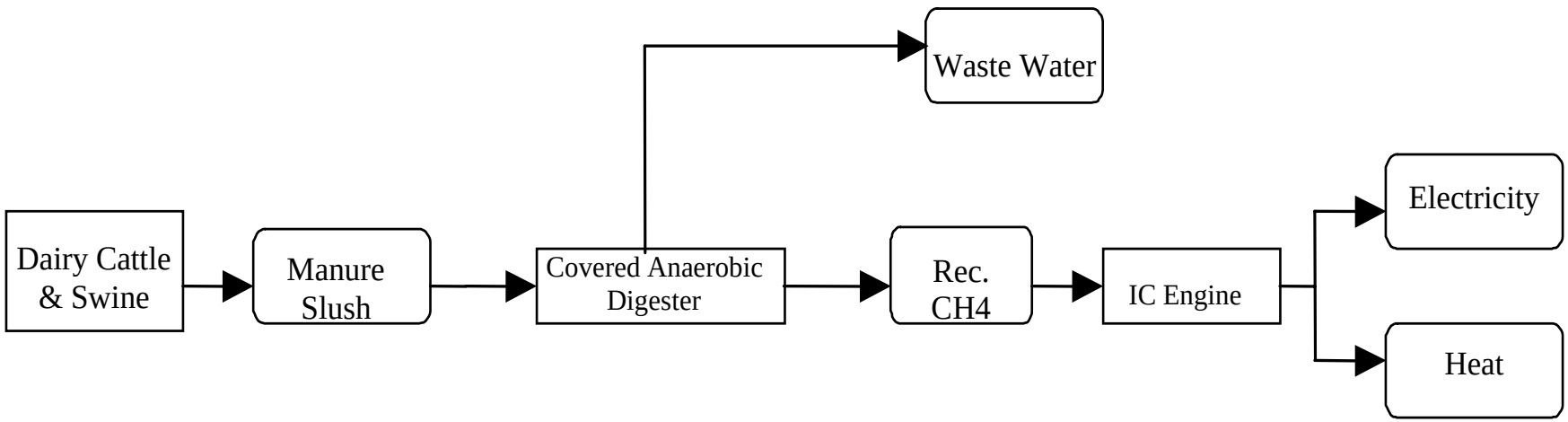
- Coal mining
  - Degasification and pipeline injection
  - Catalytic oxidation
- Oil and Gas production and supply
  - Flaring
  - Improved design and maintenance of compressors
  - Use of gas turbines for energy supply
- Manure management
  - Anaerobic digesters
- Solid waste management
  - Anaerobic digesters
  - Composting
  - Mechanical biological treatment

Emission Sources and Removal Process Linkage: Some Examples

Coal Sector:



Manure Management:



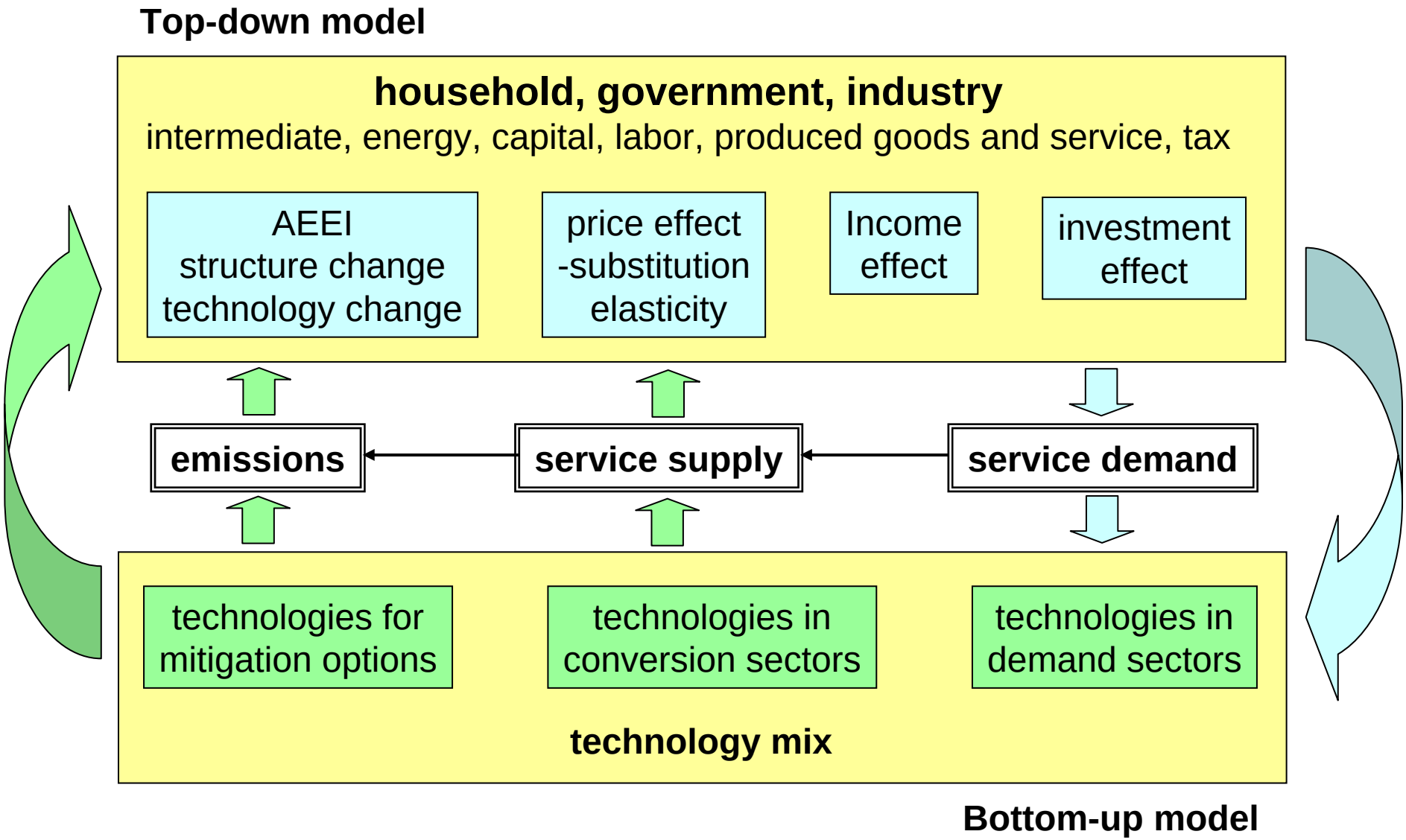
Emission Sources and Removal Processes

Emission source (CH_4)	Emissions in 2000 (MMTCE)	Driving force	Removal process considered
Coal Sector	123	Coal consumption	Degasification and pipeline injection
Enteric Fermentation	476	Livestock population	Partial replacement of Roughages with Concentrates
Manure Management	61	Livestock population	Anaerobic digester technology
Solid Waste Management	213	Urban human population	Landfill gas to electricity
Natural Gas sector	244	Natural gas consumption	Better maintenance of equipments and replacement of devices
Paddy	177	Area under cultivation	Under discussion

Key issues of non-CO2 gas abatement technology options

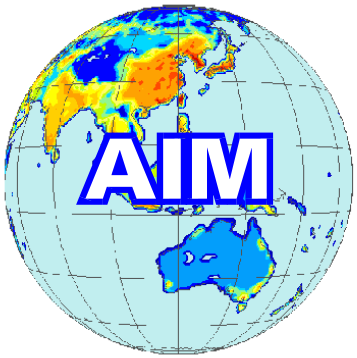
- **To evaluate ancillary benefit of non-CO2 gas abatement technology options**
  - Energy recovery from CH4 related technology options
  - Substitute fertilizer with organic one to reduce N2O and for energy saving
  - Energy saving with non-F refrigerator
- **How to diffuse agriculture related options**
  - Dispersed emission sources
  - Regional specific situation
  - Impact of global warming on agriculture sector
- **To evaluate CDM potentials**

Top-down model and Bottom-up model



Final remarks

- Develop global AIM/CGE model to evaluate multi-gas mitigation options for stabilization scenarios and estimate economic impact w/wo non-CO2 gas mitigation options.
- We are now building up technology bottom-up model to evaluate the possibility of multi-gas mitigation options and potential of CDM.
- Soft linkage between economy top-down model and technology bottom-up model will be examined.



Thank you !

Junichi FUJINO

Integrated Assessment Modeling Section
Social and Environmental Systems Division
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan
Email: fuji@nies.go.jp